ESTIMATING POPULATION PARAMETERS OF EARLY VILLAGES IN THE PRE-POTTERY NEOLITHIC CENTRAL AND SOUTHERN LEVANT

Shannon Birch-Chapman

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Supervisors: Dr Emma Jenkins, Prof. Mark Maltby and

Dr Fiona Coward

Faculty of Science & Technology
Bournemouth University

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Abstract

An understanding of population dynamics is essential for reconstructing the trajectories of central and southern Levantine Pre-Pottery Neolithic (PPN) villages during the Neolithic Demographic Transition (NDT). Whilst pre-existing population estimates of PPN villages have made a valuable contribution to our understanding of the Neolithic, these are based on limited methodological and theoretical frameworks, reducing the efficacy of these estimates for exploring the relationship between demographic parameters and socio-cultural development during this period.

The aim of this investigation is to derive more empirically and statistically robust absolute demographic data than currently exist and to produce a more precise chronology of population size, density and growth of these early villages. Several methodologies are explored, including those based on dwelling unit size and dwelling number; residential floor area per person; population density; and allometric growth formulae. The newly devised storage provisions formulae, based on the space available for sleeping individuals within structures, was found to be the most robust and viable method. A major contribution of this research is the production of precise structural contemporaneity values derived from building use-life and phase length estimates based on a combination of archaeological, ethnographic and experimental research, and Bayesian chronological modelling of radiocarbon dates.

From the results of micro-level analysis of 15 villages/village phases, a site type classification system and constants for several variables are developed for systematic application of methodologies to reconstruct population parameters of a large database of central and southern Levantine PPN villages *(n* = 106). Based on the final population estimate ranges, new allometric growth formulae are proposed for estimating PPN village populations in future from an assigned site type and total site extent.

This research has major implications for current theory relating to PPN village population density. In particular, the commonly utilised ethnographically derived population density coefficients are found to be too low to accurately estimate the population of central and southern Levantine PPN villages. In addition, the notion that nuclear families formed the predominant dwelling unit type within these villages is dismissed in favour of more variable dwelling unit composition. Finally, the population estimates produced in this investigation were assessed against the archaeological evidence to evaluate the suitability of previously hypothesised group size thresholds and to propose additional thresholds for this period relating to changing subsistence practices, the introduction of mechanisms for reducing scalar stress and the emergence of social complexity.

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Abbreviations and Definitions

a	Initial growth index for allometric growth formulae
A ≥ 60	Positive agreement threshold for Bayesian chronological models
AGF(1/2)	Allometric growth formulae based on (1) Naroll's (1962) research and (2) Wiessner's (1974) research
AMS	Accelerator mass spectrometry
ANOVA	Analysis of variance
ArcMAP10	GIS software
b	Scaling exponent for allometric growth formulae
BC/BCE	Before Christ/Christian Era
BP	Before present (before 1950)
C ≥ 95	Positive convergence value for Bayesian chronological models
Cal BC	Calibrated years before Christ
Cal BP	Calibrated years before present (before 1950)
DFA	Discriminant function analysis
DNA	Deoxyribonucleic acid: genetic structure of humans
EPPNB	Early Pre-Pottery Neolithic B
eta^2	Effect size - test statistic
FPPNB	Final Pre-Pottery Neolithic B
GADM	Global administrative areas
HUM	Housing unit method
ID	Identification
IntCal 13	Current atmospheric calibration curve for the Northern Hemisphere
LEPI	Late Epipalaeolithic
LPPNB	Late Pre-Pottery Neolithic B
LGM	Last Glacial Maximum
MPPNB	Middle Pre-Pottery Neolithic B
NDT	Neolithic Demographic Transition
OxCal	Radiocarbon date calibration software
p	Significance value for statistical tests (*p* value)
P	Population estimate
PN	Pottery Neolithic
PPN	Pre-Pottery Neolithic
PPNA	Pre-Pottery Neolithic A
PPNB	Pre-Pottery Neolithic B
PPNC	Pre-Pottery Neolithic C
PPND	Platform for Neolithic Radiocarbon Dates
RADC	Residential area density coefficient
RBAP	The proportion of contemporaneous residential built area in site area
RFAP	The proportion of contemporaneous residential floor area in site area
RPDC	Regional population density coefficient
SPDC	Settlement population density coefficient
SPF	Storage provisions formula
SPSS	Statistical software
WF16	Wadi Faynan 16: a PPNA site in southern Jordan
χ^2	Chi-square test statistic

1 Introduction

> ‘Probably few kinds of archaeological interpretation have more systematically built-in sources of potential error than have estimates of population, yet…because our concerns in archaeology turn more and more toward reconstructing social systems, we shall have to devise methods of obtaining better demographic data.’ (Hole and Heizer 1969, p.306)

The Neolithic Demographic Transition (NDT) was a period of transformation from mobile hunter-gatherer to sedentary, village-based, agro-pastoralist societies, which profoundly altered the way humans interacted with each other and their environment. This transition has been subject to considerable investigation and debate, particularly regarding the nature and extent of human interaction with, and exploitation of, the environment, including the adoption of agriculture (Colledge 2001; Kuijt and Goring-Morris 2002; Drennan and Peterson 2008; Asouti and Fuller 2013) and pastoral practices (Kuijt and Goring-Morris 2002; Makarewicz 2009; 2013; Martin and Edwards 2013); and the impact of sedentism on the environment (Rollefson and Köhler-Rollefson 1989; Simmons 2002; Campbell 2009). Other research has explored social, technological and architectural developments aimed at promoting social cohesion within larger and more densely populated sedentary settlements (Chagnon 1980; Kosse 1990; Bowser 2000; Kuijt 2000; Dunbar 2003; Bandy 2006; Düring 2013; Alberti 2014). A major research focus is the transition from curvilinear to rectilinear architecture and how this relates to changing household composition and function, and inter-household competition, which may have induced social differentiation (Flannery 1972; 2002; Banning and Byrd 1987; Wills 1992; Winterhalder 1990; Byrd 1994; Kuijt and Goring-Morris 2002; Banning 2003; Kuijt *et al.* 2011).

The transition to village society and the increasingly larger and diverse populations within these villages required significant changes to social organisation. This, combined with major developments in subsistence, technology, and ritual and symbolic practices, ultimately led to the emergence of complex societies characterised by organised social, economic, political and religious institutions (Kuijt and Goring-Morris 2002; Goring-Morris and Belfer-Cohen 2008). In order to reconstruct social developments during the NDT, a clear understanding of the key demographic parameters (i.e. size, density, growth and decline) of these early villages is essential.

Current evidence suggests that the NDT originated in the central and southern Levant during the Late Epipalaeolithic (LEPI) (c. 13,500 cal BC) when early Natufian hunter-gatherer groups established permanent (or at least semi-permanent) base-camps in resource rich areas (Bar-Yosef and Belfer-Cohen 1989, p.452; 1991, p.86; Bar-Yosef, 1998, p.168; Belfer-Cohen and Bar-Yosef 2002, p.21). However, in the later Natufian, these communities appear to have reverted to a more mobile way of life and it was not until the Pre-Pottery Neolithic (PPN) (beginning c. 10,000 cal BC) that groups of people created permanent settlements in this region, forming arguably the world's earliest sedentary villages (Goring-Morris and Belfer Cohen 1997; Bar-Yosef 1998; Kuijt 2009). Year-round habitation of these villages is suggested based on combinations of features, including the considerable durability of architectural materials and effort required for building construction (Whitelaw 1991; Dennis 2008; Balbo *et al.* 2012); the increased distinction between, and separation of, residential and non-residential built space (Byrd 1994; Rollefson 1998a; Kuijt 2000; Finlayson *et al.* 2011); subsistence strategies and storage facilities that enabled year-round food availability (Bar-Yosef and Gopher 1997; Bar-Yosef 1998; Kuijt 2008a); and the presence of human commensals (i.e. mice, sparrows and rats) that indicate continuous garbage accumulation (Bar-Yosef and Belfer-Cohen 1989; Tchernov 1991; Bar-Yosef and Meadow 1995). Ethnographic and archaeological evidence indicates that these characteristics are not always diagnostic of permanently settled communities, as inhabitants may move to seasonal camps, particularly during summer (Bar-Yosef and Belfer-Cohen 1989; 1992; Boyd 2006). However, the combined presence of these features within many PPN settlements provides reasonable justification for their interpretation as sedentary (or predominantly sedentary) communities.

There is some debate regarding the use of the term 'village' to describe these early settlements. The modern definition of the term denotes a self-contained settlement of a cluster of structures, including dwellings and associated buildings, usually in a rural setting (Oxford Dictionaries Online 2016). According to the 'Domesday Project', essential village characteristics in Britain include residential structures (i.e. dwellings) and non-residential structures and open areas used for ritual (i.e. a church), communal (i.e. a village hall or community centre, a public house and a village green) and decision-making (i.e. a parish council) activities, and/or as places of work (i.e. shops and allotments) (Cellan-Jones 2011). The term 'hamlet' refers to small modern settlements lacking non-residential structures (Parsons 1971, p.22; Blanton 1972, p.20) and is, thus, sometimes applied to early Natufian base-camps (Bar-Yosef and Belfer-Cohen 1989, p.490; 1991, p.86; Bar-Yosef 1998, p.168).

Many central and southern Levantine PPN settlements demonstrate village characteristics. The majority of structures within permanent PPN settlements are identified as residential based on interior domestic features (i.e. hearths and sleeping platforms/compartments), evidence for food-related activities within structures and associated annexes, and consistent architectural morphology (Watson 1978; Kramer

1982; Byrd 2002; 2005a). These dwellings were occupied by permanent (or at least predominantly-permanent) co-resident units for relatively long periods (Kuijt 2000). Open areas for communal activities, such as food processing, cooking and feasting (Twiss 2008), were a common feature, with the majority of settlements also containing non-residential structures for ritual, communal, storage and workshop activities. These non-residential structures are usually identified by their distinctive form and layout, unique interior features and associated non-residential structures and communal areas (Rosenberg and Redding 2002; Byrd 2005a; Bar-Yosef *et al.* 2010a; 2010b). Byrd (1994, p.643) interprets large communal structures as representing the establishment of supra-household corporate groups to facilitate group decision-making and social cohesion within larger populations. Open and built area for non-residential activities became increasingly structured and formalised throughout the PPN (Byrd 2002). The presence of these formal village characteristics within many PPN settlements provides reasonable justification for their interpretation as early and/or formative villages.

The fundamental re-structuring of human societies into village settlements occurred throughout the world in different time periods, making this transitional period highly relevant for comparative analysis of cultural and social evolution on a global scale (Bandy 2005; Bocquet-Appel and Bar-Yosef 2008). The causes, motivations and consequences of the central and southern Levantine NDT have been subject to extensive investigation. However, to date, there has been limited progress towards producing the accurate absolute estimates of PPN village population size, density and dynamics that are essential for reconstructing the trajectories of these early village societies. This is largely due to the methodological difficulties associated with reconstructing population estimates.

The few investigations that have produced absolute estimates of demographic data for multiple central and southern Levantine PPN villages have reconstructed this data as part of broader investigations into processes of socio-cultural development during the NDT rather than as absolute representations of past populations (Kuijt 2000; 2008a; Campbell 2009). For example, Kuijt (2000, p.81) estimated the population size of 25 settlements from the Late Natufian to the Pre-Pottery Neolithic C (PPNC) to explore the relationship between population growth, sedentism, food production, social crowding and social inequality. In a later investigation, Kuijt (2008a, pp.293-295) estimated and assessed diachronic variations in population size, settlement size and the ratio of built to open space to explore the relationship between food storage and sedentism during the NDT. In another study, Campbell (2009) established low, mid-range and high population estimates for PPN villages at ‘Ain Ghazal, Basta and Jericho to explore the environmental impact of agricultural practices employed by groups of different sizes.

Due to the comparative focus of each of these investigations, emphasis on the accuracy of the population estimates themselves is limited. In each of these cases, the same basic methodology was employed to calculate population size based on total site extent and a narrow selection of population density coefficients derived from ethnographic analysis of Southwest Asian villages (Jacobs 1979; Watson 1979; Kramer 1982; van Beek 1982). These investigations, while valuable, do not adequately critically assess the suitability of ethnographic comparatives or the underlying theoretical and methodological assumptions associated with this method.

Further limitations of pre-existing estimates include few attempts to estimate the number of people per dwelling or the amount of space per person. This is largely due to methodological issues regarding the identification of habitable and/or residential area and theoretical issues relating to the composition of dwelling units, particularly the type of family unit and the ratio of children to adults, as well as the potential use of space for animals.

Given the pivotal role of the central and southern Levant during the NDT and the importance of this region for understanding early village development, the limited number of investigations that have attempted to reconstruct absolute estimates of PPN village population parameters is surprising. In addition, a revision of the theoretical and methodological framework underpinning these reconstructions, including the use of ethnographic comparatives from Southwest Asia, is long overdue. If more insightful conclusions are to be made regarding the development of these early village societies, more precise and accurate estimates based more heavily on empirical archaeological evidence are required.

1.1 Aims and objectives

The purpose of this PhD research is to establish a more empirically and statistically robust methodology for estimating the population parameters of central and southern Levantine PPN villages. It is expected that the final methodologies presented in this research will be easily applied (and adapted) by archaeologists in future to produce more precise and accurate absolute estimates of early village population parameters both within and beyond this time period and region. Compared to previous investigations, this analysis proposes site-specific population size and density estimates for a considerably larger number of central and southern Levantine PPN villages and village phases (n = 106). The estimates proposed in this research have the ability to enhance our understanding of the demographic trajectories of these early sedentary societies by facilitating more meaningful analyses of the relationship between demographic parameters and developments during the NDT, including major transitional stages relating to subsistence, architecture, technology, culture and social organisation.

Aim 1: establish a more empirically and statistically robust methodology for estimating population size, density and dynamics of central and southern Levantine PPN villages at the micro-level (i.e. individual site analysis) and for systematic application to numerous sites.

Objectives:

- Evaluate a range of modern demographic, ethnographic and archaeological methodologies for estimating population size, density and dynamics of early and formative village societies.
- Identify the most appropriate methodologies for estimating population size, density and dynamics of central and southern Levantine PPN villages, taking into consideration the environmental conditions, archaeological features and social processes that existed during the PPN.
- Apply selected micro-level methods to a test site with multiple phases (Beidha) to determine the suitability of the methods and to refine the methodology prior to application to other sites.
- Apply refined micro-level methodologies to selected PPN villages to estimate population size, density and dynamics.
- Establish a site type classification system that can be easily applied by archaeologists in future.
- Determine universal and site type constants for data required for systematic methodologies.
- Apply systematic methodologies to PPN villages identified (in this study) within the central and southern Levant to rapidly estimate demographic parameters based on site extent, site type and associated constants.
- Determine the most suitable methodologies for the systematic reconstruction of estimates by:
    - examining the differences between estimates derived from micro-level and systematic methodologies to determine the accuracy of the systematic methods; and,
    - eliminating systematic methods that produce excessive population estimate ranges.
- Establish final population estimate ranges for each PPN village identified in the central and southern Levant.

- Develop site type and universal formulae to estimate the minimum, mean and maximum population of PPN central and southern Levantine villages.

Aim 2: produce a precise chronology of population size, density, growth and decline of central and southern Levantine PPN villages in order to facilitate further investigation into the relationship between population change and socio-cultural development during the PPN.

Objectives:

- Establish estimates of population size and density for each PPN village identified (in this study) within the central and southern Levant.
- Identify patterns in population size, density and dynamics throughout each period.
- Determine the rate of population growth or decline throughout the PPN in this region.
- Explore a major theoretical aspect that can be enhanced by more precise and accurate population estimates (i.e. the relationship between group size and specific developments during the PPN).

1.2 Thesis structure

The next chapter (Chapter 2) outlines the geographical and environmental background of the central and southern Levant, including modern and palaeoenvironmental conditions, providing the environmental context for the PPN and justification for the use of specific ethnographic comparatives. This is followed by a summary of the chronological sequence for the PPN, including major aspects of village development throughout each PPN period (Chapter 3).

In Chapter 4, commonly utilised methodologies for estimating population parameters of early villages are evaluated, followed by a summary of existing estimates of population parameters for PPN central and southern Levantine villages. This chapter includes a brief discussion of the impact of group size on cultural evolution, identifying some of the major pre-existing hypothesised group size thresholds relevant to the PPN.

The methodology chapter (Chapter 5) describes the process for the selection and preparation of data, including the selection of sites for inclusion in the PPN village database and for micro-level assessment; and the criteria for identifying dwellings and residential area. In addition, this chapter provides the methodology for establishing the most precise site extent estimates based on the information available, and outlines the process for digital transcription of site plans. This is followed by an explanation of the micro-level and systematic methods employed for estimating population parameters.

The results of the micro-level application of methodologies to the PPNB village at Beidha, southern Jordan, are presented in Chapter 6. This includes a detailed description of the use of Bayesian chronological modelling of radiocarbon dates to estimate building use-life and phase length in order to reconstruct structural contemporaneity values.

The application of micro-level methodologies to a further 11 PPN central and southern Levantine villages/village phases is presented in Chapter 7. The results of micro-level analyses are assessed in order to develop a site type classification system and constants to systematically reconstruct population estimates for all sites in the central and southern Levantine PPN village database.

The results of this systematic application are presented in Chapter 8. This chapter provides descriptive statistics relating to site extent, predominant architectural form and site type for the village database as a whole, followed by a detailed analysis of systematic methodologies in order to establish a final population estimate and density values for each village. These estimates are assessed against pre-existing hypothesised group size thresholds relating to three major aspects of cultural evolution during the NDT: changing subsistence practices; the introduction of mechanisms for reducing scalar stress and promoting social cohesion; and emerging social complexity. Summaries of density estimates per site type and population growth rates per PPN period are presented. Finally, a series of site type and universal formulae are proposed for estimating PPN village populations in future.

In Chapter 9, current theory relating to population density is re-evaluated. This includes a critical assessment of assumptions relating to dwelling unit size and composition, and the use of ethnographically derived population density coefficients to estimate population. The major methodological contributions of this research are discussed, including the preferred method proposed for estimating population at the micro-level (i.e. the storage provisions formulae); the use of Bayesian chronological modelling for reconstructing structural contemporaneity values (i.e. the percentage of structures in simultaneous use); the new site type classification system; and the newly proposed formulae for estimating PPN village populations. Finally, the revised population estimates are assessed against the archaeological evidence to propose potential group size thresholds specific to central and southern Levantine PPN villages.

The final chapter (Chapter 10) presents an overall summary of the investigation, including major conclusions and avenues for further work.

2 The Geographical and Environmental Background

The interrelationship between the physical geography of a region and its climatic conditions directly influences habitation by living organisms and must be considered in order to fully understand human occupation and development. Human beings continually make decisions relating to their surroundings and adapt to new situations. In the Levant, human adaptive responses to long-term and rapid environmental changes are considered an important factor in the development of sophisticated technological, social, economic and political strategies, many of which have persisted to this day (Henry 1997). As such, an understanding of the impact of geography and environment on human behaviour is critical for investigating the adaptive strategies developed during the late Epipalaeolithic and Neolithic periods, and for sourcing suitable ethnographic comparatives. Although present communities are unlikely to exactly mimic those of the past, historical and ethnographic evidence can provide suitable comparative data, particularly where comparable environmental conditions and behavioural practices exist (Bocquet-Appel *et al.* 2005).

This chapter outlines the geographic and environmental background of the central and southern Levant. This includes a summary of the modern geographical and environmental conditions, providing the context for commonly utilised Southwest Asian ethnographic comparatives; and a summary of geographical and environmental reconstructions from the Last Glacial Maximum (LGM) (c. 20,000 cal BC), providing the context for Pre-Pottery Neolithic (PPN) sites.

2.1 The study area

The investigation area focusses on the central and southern Levant which forms part of the Fertile Crescent: an area of nutrient-rich land along the main watercourses from the Red Sea to the Arabian Gulf, via Turkey (Figure 2.1). The Levant refers to an area of cultural habitation. The central and southern Levant extends from the Gulf of Aqaba, along the Mediterranean coast to the mouth of the Orontes River, and is bounded by the Syro-Arabian desert to the east. This area covers the southernmost point of Turkey; Syria southwest of the Euphrates; Lebanon; the Palestinian Territories; Israel; and the western part of Jordan (Sabatinelli 2008). The central and southern Levant is of high global significance as it contains some of the earliest evidence for sedentism, agriculture and pastoralism, and serves as a land bridge between the peoples and cultures of Europe, Asia and Africa (Killebrew and Steiner 2013, p.2).

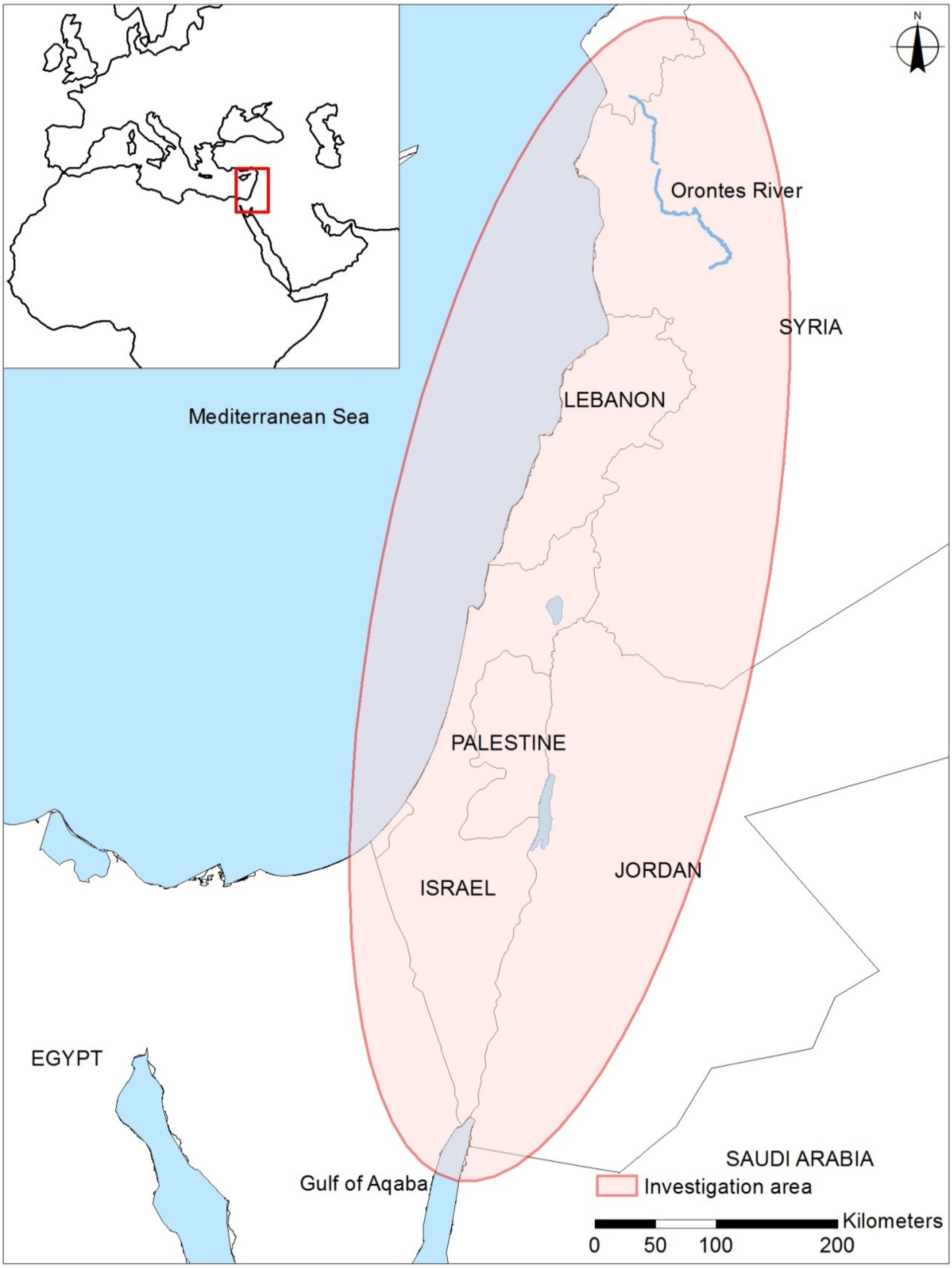


Figure 2.1. The location of the investigation area: the central and southern Levant (administrative boundaries from Global Administrative Areas (GADM) Version 1, 2009).

2.2 Current geographical and environmental background

The investigation area covers approximately 500,000 km^2, spanning relatively temperate regions along the Mediterranean coast and relatively arid regions, including the Syro-Arabian desert, to the east (Figure 2.2). The variable topographical and environmental conditions have produced a series of distinctive habitats, which can be broadly divided into four longitudinal geomorphological zones: the Mediterranean coastal plain, the Syro-African Rift Valley, the highlands and the Syro-Arabian desert (Colledge 2001, p.1; Suriano 2013, p.9) (Figure 2.3). The following sections provide a description of these geomorphological zones, with reference to the physical geography, climatic conditions, and floral and faunal elements (Figures 2.4-2.7).

The Mediterranean Coastal Plain

The Mediterranean coastal plain stretches discontinuously along the eastern shoreline of the Mediterranean Sea. Along the Palestinian-Israeli coast, the plain is composed of sandy and alluvial soils with mobile sand dunes occupying a maximum width of around 60 km (Colledge 2001, p.1). In the north, the coastal plain varies in width from around one to nine km and is dissected in several areas by mountainous slopes (Asmar 2011, p.10). Annual rainfall varies from 350 mm to 1,000 mm in the temperate north and up to around 400 mm in the more arid and steppic south (Figure 2.4). The coastal plain is inhabited by temperate Atlantic-Mediterranean vegetation, including carob, thatching grass, meadow oat grass, evergreen shrubs and oak (Masri 2006, p.7; Sabatinelli 2008) (Figure 2.7). Cultivated fruits include citrus and banana (Asmar 2011, p.10). The low slope gradient (0°-8°) and easy access to water resources provide excellent conditions for human habitation.

The Syro-African Rift Valley

The Syro-African Rift Valley and adjacent highlands form a natural barrier between the Mediterranean coastal plain and the Syro-Arabian desert (Suriano 2013, p.10). The valley is up to 15 km wide and extends from the Orontes River to the Gulf of Aqaba, through the Bekaa and Jordan Valleys and the Wadi Araba. The valley contains the modern remnants of the large ancient Lake Lisan: Lake Tiberius (the Sea of Galilee) and the Dead Sea (Colledge 2001, p.1; Suriano 2013, pp.9-10). Elevation above sea level ranges from -396 m (the lowest dry point on Earth located on the shores of the Dead Sea) to around 1,000 m in the Bekaa Valley, Lebanon (Figure 2.6). Average annual precipitation in the north (c. 100-400 mm) is generally much higher than in the xero-trophic conditions of the south (c. 50-100 mm), where rainfall is almost absent during the summer months (Zohary 1942, p.203; Colledge 2001, p.1) (Figure 2.4).

Varied climatic conditions have produced significantly different vegetation regimes along the rift with a variety of Mediterranean, Irano-Turanian and Sudanian vegetation in moister regions and Saharo-Arabian vegetation in the more arid southern regions (Zohary 1942, p.202) (Figure 2.7). Differing hydrological and vegetative formation processes have produced fertile alluvial soils in some parts and dry soils with low organic content in others (Colledge 2001, p.1). Permanent water sources, such as the Orontes and Yarmouk Rivers, provide grazing areas and important agricultural regions for the cultivation of vegetables, fruit (i.e. citrus and banana) and crops (i.e. lucerne) (Abusetta Al-Jaloudy 2006).

The Highlands

The Levantine highlands almost continuously border the Syro-African Rift Valley. On the west are the Syrian Coastal and Lebanon Mountain Ranges and the Negev Highlands; and on the east, the Eastern Lebanon Mountain Range (Anti-Lebanon Mountains), and the Golan and Jordanian Heights. Elevation above sea level ranges from around 600 m to 1,500 m in the north and south, with higher altitudes than these in the central regions. The highest point (3,088 m) occurs in the Lebanon Mountain Range (Figure 2.6). Average annual rainfall is less than 80 mm in the southern arid regions, and around 200 mm to 300 mm in the semi-arid highlands, plains and plateaus. Higher annual rainfall (> 400 mm) is recorded in the Mediterranean-facing coastal highlands and in the Syrian highlands during the winter months (Abusetta Al-Jaloudy 2006; Corradi 2006, p.11; Al-Jawarneh 2008; Avni *et al.* 2012, p.14) (Figure 2.4). Average annual temperature ranges from around 10ºC to 20ºC depending on altitude (Hijmans *et al.* 2004; Avni *et al.* 2012, p.14) (Figure 2.5).

Fertile soils support Mediterranean woodland and forests of evergreen, conifer and deciduous trees, particularly oak varieties, and shrub lands in more moist areas (Zohary 1942, p.1; Colledge 2001, p.211; Corradi 2006, p.11; Sabatinelli 2008). Within drier areas, less fertile and rockier terrain supports Irano-Turanian steppe grasses and shrubs (Sabatinelli 2008; Avni *et al.* 2012, p.14) (Figure 2.7). The Jordanian highlands contain shallow, heavy clay soils with high water holding capacity (Al-Jawarneh 2008, p.15).

Several permanent and seasonal wadi systems (i.e. seasonally flowing rivers) dissect the highlands, including Wadis ar-Ruyan and Zurayqun in Lebanon, and Wadis Faynan, Rummen and el-Hasa in Jordan. These areas are most attractive for human occupation due to the more moist and fertile conditions suitable for cultivation and pastoral practices. Terraced plots throughout the highlands are also used to cultivate cereals (i.e. wheat and barley), fruit trees and Mediterranean crops specially adapted to desert environments, such as almonds, olives, figs and grapes (Abusetta Al-Jaloudy 2006; Avni *et al.* 2012, pp.15 and 24).

The Syro-Arabian Desert

The Syro-Arabian Desert lies to the east of the Syro-African Rift Valley and eastern highlands. It includes the Syrian and Jordanian Badias, which cover 55% and 80% of their respective countries, and comprise generally uncultivable and uninhabitable desert and steppe regions with occasional vegetated wadis and semi-arid rangelands. Elevation above sea level is around 600 m to 900 m. The average annual rainfall is less than 50 mm. Temperatures wary widely from below 0ºC to over 40ºC (Jordan LESA 2014) (Figure 2.5). The underlying geology of black basalt boulders and limestone plateaus has resulted in largely unproductive areas with discontinuous Saharo-Arabian drought resistant vegetation interspersed with large barren areas (Colledge 2001, p.3; Abusetta Al-Jaloudy 2006; Jordan LESA 2014).

Human habitation is confined to the vegetated wadis, such as the Azraq Basin, and areas irrigated by underground water, which enable growth of Irano-Turanian vegetation, including small annuals, grasses and legumes (Sabatinelli 2008). These areas are utilised for pastoral activities and cultivation of cereal crops, including barley, vegetables and fruits, particularly tomatoes and watermelons (Abusetta Al-Jaloudy 2006; Louhaichi *et al.* 2012, p.102). The rangelands are also used extensively for pastoral activities, particularly sheep, goat and camel grazing (Abusetta Al-Jaloudy 2006).

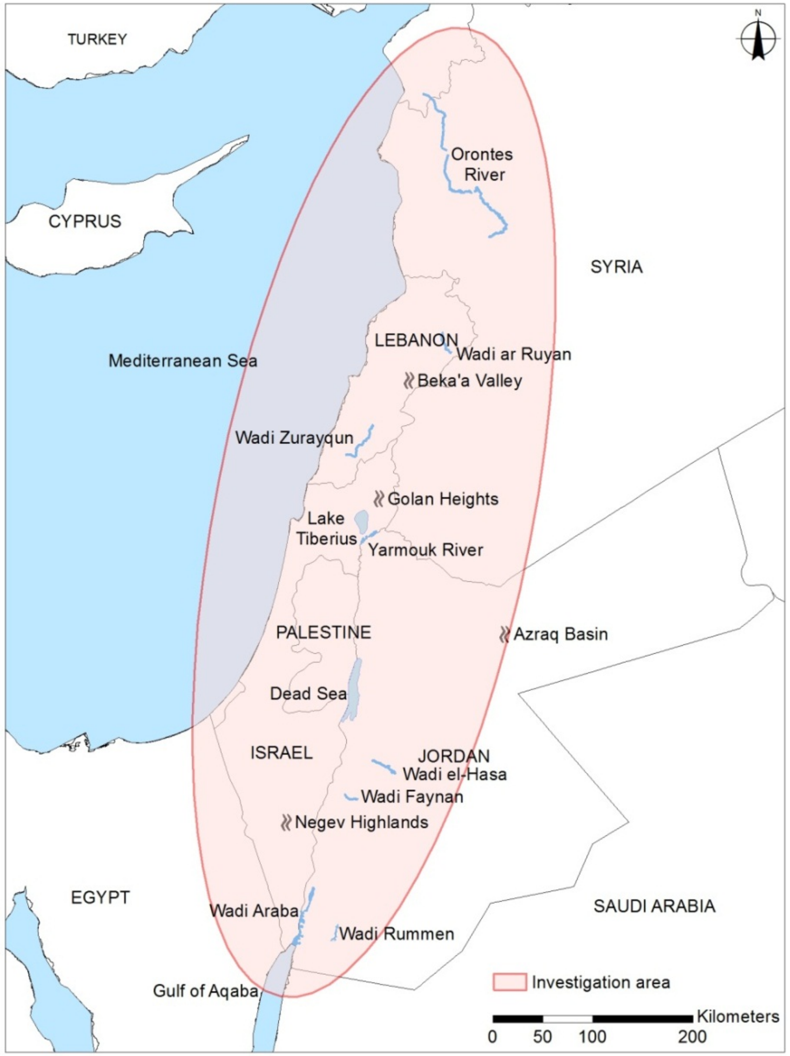


Figure 2.2. Modern sites and regions mentioned in the text (administrative boundaries from Global Administrative Areas (GADM) Version 1, 2009).

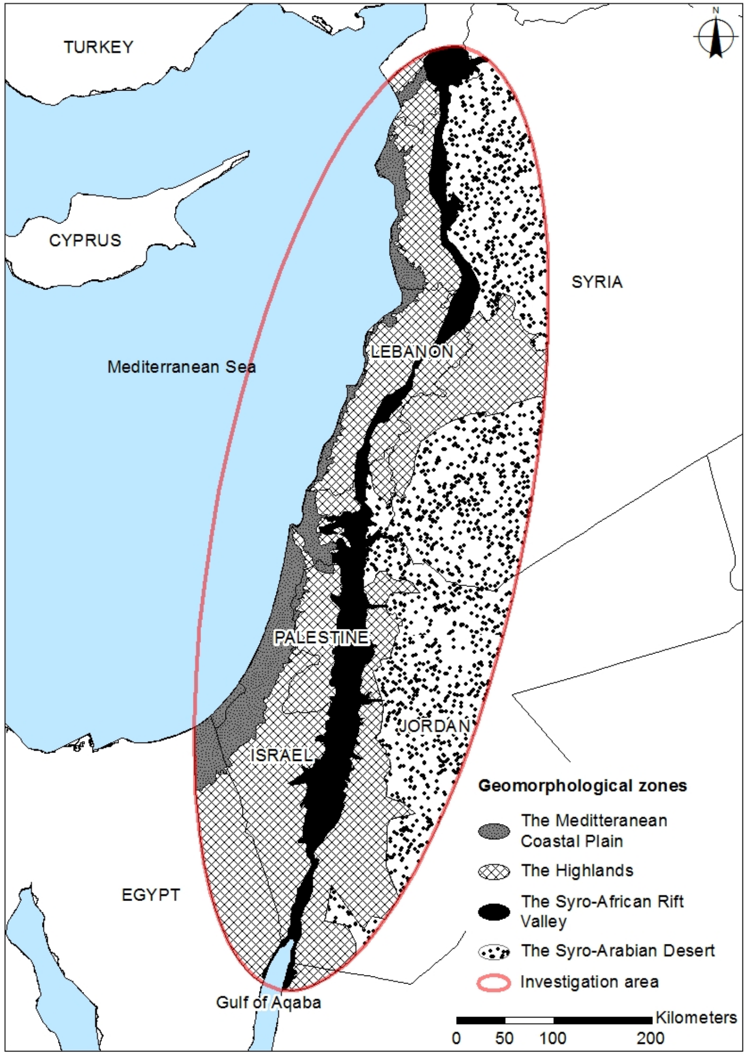


Figure 2.3. The four major geomorphological zones (administrative boundaries from GADM Version 1, 2009).

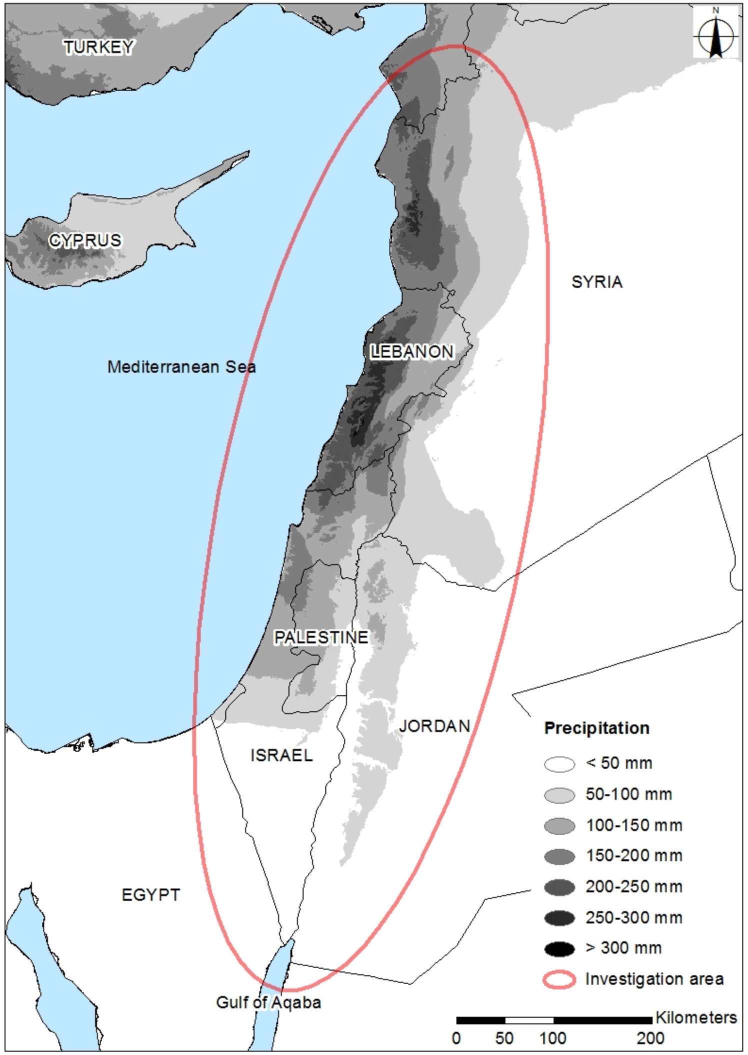


Figure 2.4. Average annual precipitation (data from WorldClim; Hijmans *et al.* 2005; administrative boundaries from GADM Version 1, 2009).

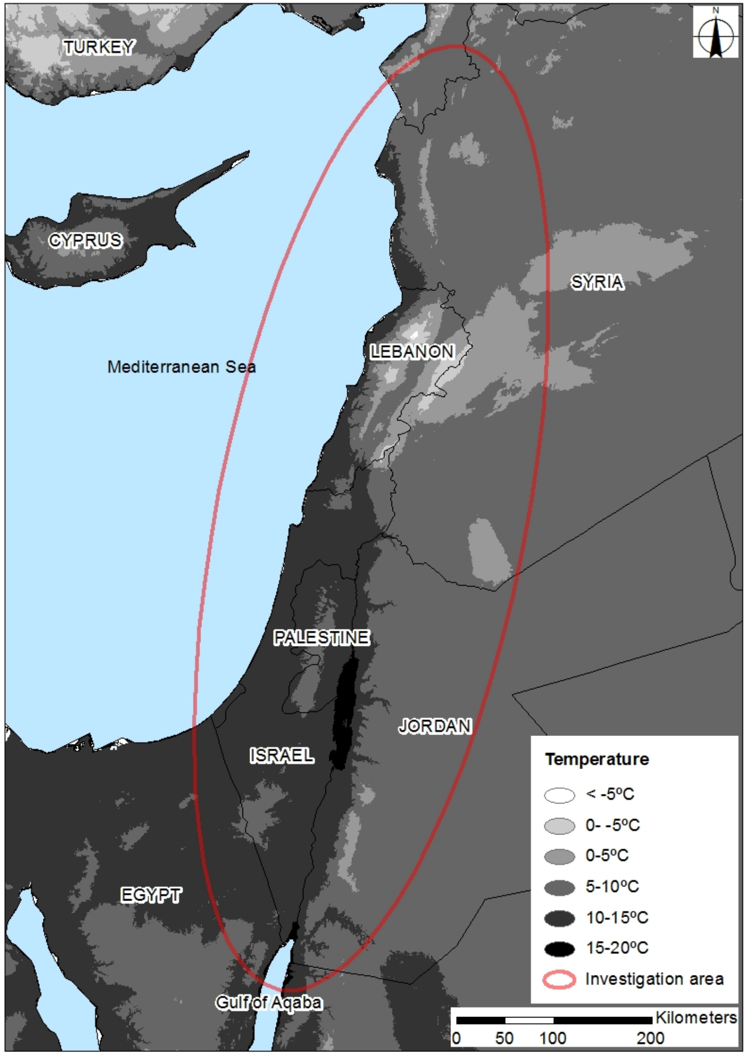


Figure 2.5. Mean annual temperature (data from WorldClim; Hijmans *et al.* 2005; administrative boundaries from GADM Version 1, 2009).

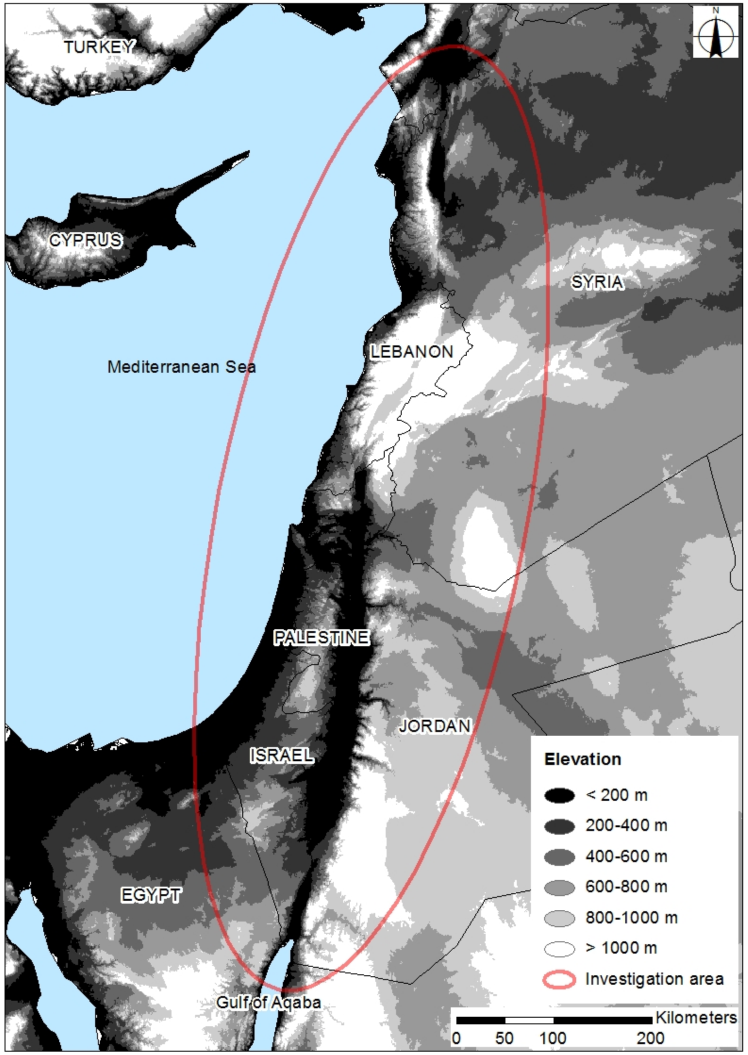


Figure 2.6. Elevation (data from WorldClim; Hijmans *et al.* 2005; administrative boundaries from GADM Version 1, 2009).

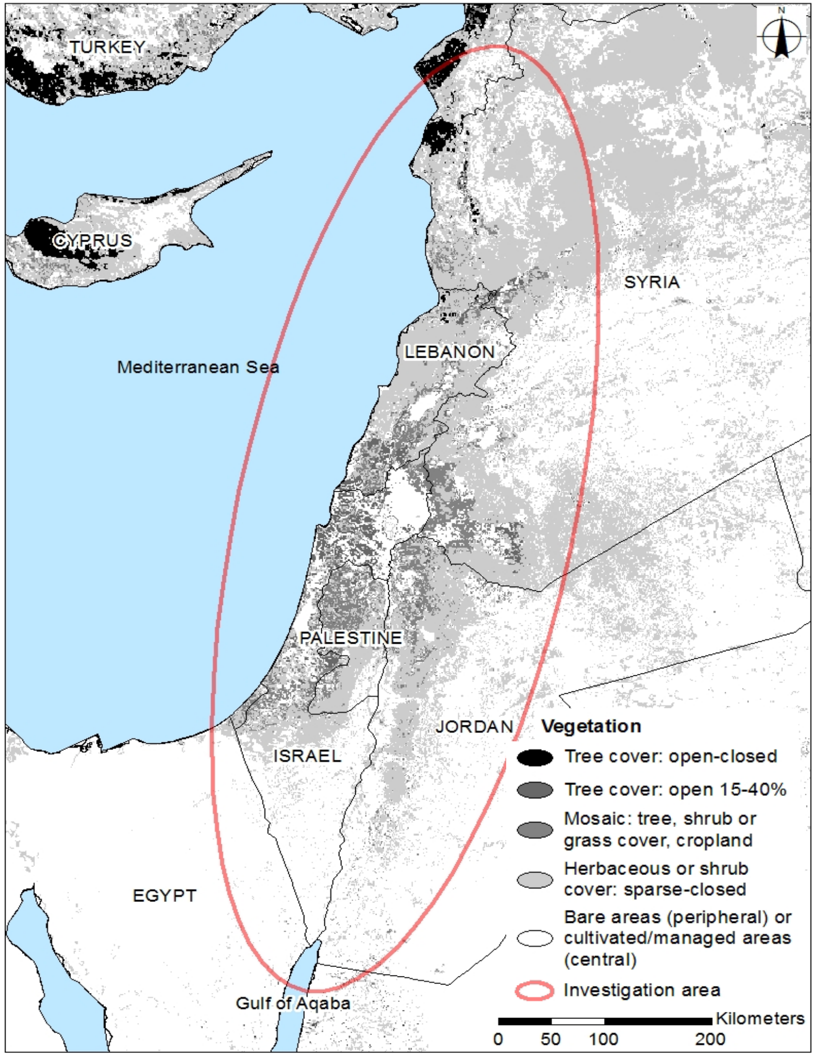


Figure 2.7. Modern land cover (land cover data from GADM 2012; administrative boundaries from GADM Version 1, 2009).

2.3 Palaeoenvironmental reconstruction

The environmental history of the central and southern Levant has changed considerably since early human habitation during the Pleistocene. Palaeoclimate proxy sites in the region, such as Lake Huleh (Baruch and Bottema 1999; Meadows 2005), Soreq Cave (Bar-Matthews *et al.* 1999) and Mount Sedom (Frumkin *et al.* 1991; 1994) in Israel, and the Ghab Valley in Northwest Syria (Yasuda *et al.* 2000) (Figure 2.8) have revealed a generalised climatic trend from cold, glacial conditions during the Pleistocene to more temperate, warmer and wetter conditions during the early Holocene, followed by a deterioration of environmental conditions from the mid-Holocene (Robinson *et al.* 2006, p.1517) (Figures 2.9-2.11).

It has been argued that human adaptive strategies in this region were largely in response to changes in access to water and water-dependent resources (Robinson *et al.* 2006, p.1521). The location of the Levant on the border of vastly different climatic zones (i.e. the moist Mediterranean Sea, dry desert regions and cold mountainous regions) increases its sensitivity to climatic changes. As such, the Levant has experienced relatively rapid environmental change, requiring swift implementation of adaptive strategies. The major climatic shifts that have impacted socio-cultural development in the central and southern Levant include those which occurred at the end of the Last Glacial Maximum, and during the Bølling-Allerød Würm Interstadial, the Younger Dryas and the Holocene.

2.3.1 End of the Last Glacial Maximum c. 20,000 cal BC

During the Last Glacial Maximum (LGM), extensive ice sheets produced colder and more arid climatic conditions (Yechieli *et al.* 1993). Speleothem data from Soreq, Peqiin and Ma'ale Efrayim Caves, in Israel, show high $\delta^{18}O$ values (i.e. the ratio between ^{18}O and ^{16}O isotopes), indicating lower temperatures and less rainfall (Bar-Matthews *et al.* 1997, p.162; 1999, p.89; McGarry *et al.* 2004, p.931). General circulation models have indicated reduced average annual precipitation of around 250 mm to 400 mm and lower average daily temperatures of around 12ºC to 19ºC (Robinson *et al.* 2006, p.1535) (Figures 2.9-2.10). Increasingly arid conditions caused sea and lake levels to lower significantly (Bar-Matthews *et al.* 1997, p.164; 1999, p.91; Abed and Yaghan 2000; McLaren *et al.* 2004, p.134). A reduction in tree pollen indicates reduced forest growth (Rossignol-Strick 1995, p.913), whilst rising $\delta^{13}C$ (i.e. the ratio between ^{13}C and ^{12}C isotopes) indicates a proliferance of more arid C_4 plant varieties that are restricted to areas with annual rainfall of less than 300 mm (Bar-Matthews *et al.* 1997, p.162; 1999, p.91; Goodfriend 1999, p.503).

2.3.2 Bølling-Allerød Würm Interstadial c. 13,000-11,000 cal BC

During the Bølling-Allerød Würm Interstadial, warmer daily average temperatures (c. 18ºC) and increased annual average precipitation (c. 550-750 mm) caused rising lake levels and increased hydrological activity (Goodfriend and Magaritz 1988). Speleothem data from Soreq Cave and pollen analysis from the Ghab Valley indicate increased growth of C_3 plants, such as cereals (i.e. barley), vegetables and fruits, and forest trees, particularly oak (Rossignol-Strick 1995; Bar-Matthews *et al.* 1997; 1999; Yasuda *et al.* 2000). The presence of perennial water sources has been linked to the establishment of more permanent Natufian hunter-gatherer base-camps during this period (Bar-Yosef and Belfer-Cohen 1992; Bar-Yosef 2000).

2.3.3 Younger Dryas c. 11,000-9,600 cal BC

Evidence indicates that conditions during the Younger Dryas were generally more arid and cool, with mean annual daily temperature of around 13ºC. Two climatic sub-regions existed: a moister region in the north with continued forest cover; and an extremely arid region in the south (Rossignol-Strick 1995; Bar-Matthews *et al.* 1997, p.165; 1999, p.91; 2000, p.151; Baruch and Goring-Morris 1997, pp.257-258; Colledge 2001, p.4).

Analysis of palaeosols indicates that large amounts of dust were transported from southern deserts. The arid southern regions, which received average annual rainfall of less than 150 mm, were dominated by C_4 plants, including hardy, flowering shrubs and grasses (Baruch and Bottema 1999; Gvirtzman and Wieder 2001, p.1827). Large Pleistocene lakes, such as Lake Lisan, contracted, leaving layers of salt deposits (Yechieli *et al.* 1993, p.63; Colledge 2001, p.4; Robinson *et al.* 2006, p.1524). It has been argued that the variable access to water and other resources during this period caused some semi-sedentary hunter-gatherer communities to return to a more mobile existence (Bar-Yosef and Belfer-Cohen 1992; Bar-Yosef 2000).

2.3.4 The Holocene c. 9,600 cal BC - present

The early Holocene was characterised by the wettest climatic conditions of the past 25,000 years, with higher annual precipitation (> 240 mm) and increased average daily temperatures (c. 14-17ºC) (Frumkin *et al.* 2001, p.1183). Speleothem data, palynological evidence, lake level evidence and fluvial deposits indicate a wetter climate resulting from a northern extension of monsoonal weather from the Indian Ocean (Arz *et al.* 2003, p.121). Lake levels rose significantly and salinity reduced in the Mediterranean and Red Seas (Arz *et al.* 2003, p.120). Increased hydrological activity produced perennial streams and enhanced wadi systems providing year-round access to water and nutrient-rich, fertile sediments, even in more arid regions (Hunt *et al.* 2004, p.922). These conditions were more favourable for sedentary subsistence practices, including agriculture and pastoralism, and are considered by many to be the catalyst for the Neolithic Demographic Transition (NDT) (Bar-Yosef 1998; 2000).

In more arid regions, vegetation was most prevalent around wadis, which accumulate highly productive alluvial fans (Petrie and Thomas 2012, p.1056). It has been suggested that the restricted nature of these productive zones and the limited potential for cereals to grow naturally in these areas required communities to re-sow crops intentionally, eventually producing morphologically domesticated species (Sherratt 2007, pp.8-10). Access to water and the ability to cultivate crops are major facilitators of long-term settlement. As such, seasonal water sources are often artificially enhanced to prolong water availability. Some of the earliest examples of water management in the central and southern Levant include wells at the Pre-Pottery Neolithic C (PPNC) site of Atlit-Yam in Israel (c. 6,700 cal BC) (Galili and Nir 1993); and brushwood and earth dams at the Pottery Neolithic site of Dhra' in Jordan (c. 6,000 cal BC) (Kuijt *et al.* 2007).

Increased rainfall and milder temperatures significantly reduced arid C_4 vegetation and encouraged growth of C_3 plant varieties, including oak and pistachio (Rossignol-Strick 1995, pp.908-909; Goodfriend 1999, p.196; Hunt *et al.* 2004, p.925). Ratios between C_4 and C_3 vegetation indicate that annual rainfall averages of less than 200 mm occurred 20 km further south than presently, sustaining moisture-dependant Irano-Turanian vegetation rather than the Saharo-Arabian varieties that dominate the area today (Goodfriend 1999, p.196). Analysis of charcoal from settlements at 'Ain Ghazal and Basta, and pollen from Nahal Divshon, indicate that the average annual rainfall was around 50 mm to 100 mm higher than at present (Horowitz 1976, p.59; Neef 2004, p.298).

Faunal evidence for fallow deer and wild cattle indicates extensive woodland and open scrubland (Tchernov 1976, p.69). Perennial freshwater ponds and open water supported a variety of species, including water fowl and catfish (Bar-Yosef 1984, p.153). The limited evidence for ovicaprines (goats and sheep) in steppe environments suggests that rainfall was not sufficient in these regions to support wild herds, which require daily water (Baird 1993, p.44). These more arid regions were inhabited by gazelle, foxes, jackals, ostriches and wild boar (Betts 1998, p.151). Archaeological evidence suggests that gazelle formed the predominant food source prior to the domestication of goats and sheep during the Middle Pre-Pottery Neolithic B (MPPNB) (Bar-Yosef 1998, p.168).

At around 6,200 and 2,200 cal BC, there were major climatic events characterised by rapid cooling and reduced precipitation related to North Atlantic climate fluctuations (Bond *et al.* 1997; 2001; Bar-Matthews and Ayalon 2011, p.163). These events have been associated with the abandonment of later PPN sites in the Jordan Valley and the Bronze Age Akkadian civilisation, respectively (Cullen *et al.* 2000; Mithen 2003). From the mid-Holocene (c. 4,000 cal BC), climatic conditions deteriorated considerably, causing desiccation of water sources and the retreat and replacement of forests by steppe vegetation and drought resistant plants (Bar-Matthews *et al.* 2000, p.151; Frumkin *et al.* 2001, p.1184; Hunt *et al.* 2004, p.926; Avni *et al.* 2012) (Figure 2.11). These conditions have continued relatively unchanged to the present day (Robinson *et al.* 2006, p.1521 and 1537).

2.4 Summary

This chapter has provided the environmental context for this investigation. A review of the current environmental conditions and palaeoenvironmental reconstructions emphasises the importance of adaptation for socio-cultural development in this region. The oscillation between cold/dry conditions and warm/wet conditions over the past 21,000 years has induced relatively fast adaptations in subsistence strategies, varying between mobile hunter-gatherer and settled agro-pastoralist economies depending on the environmental conditions. The period under investigation (the PPN, c. 10,000-6,000 cal BC) roughly corresponds to the early Holocene. Palaeoenvironmental and palaeoclimatic data indicates that environmental conditions during this period were more temperate than at present, with milder average daily temperatures (c. 14-17ºC) and higher average annual precipitation (c. 240 mm) (Frumkin *et al.* 2001; McGarry *et al.* 2004). Increased hydrological activity provided constant access to freshwater and fertile sediments (Arz *et al.* 2003; Hunt *et al.* 2004). Mediterranean vegetation dominated the area, with more arid Irano-Turanian vegetation in the south and in drier marginal zones (Goodfriend 1999). These environments supported a large variety of land animals and freshwater species (Bar-Yosef 1984; 1998; Baird 1993). The considerable differences between the warm and moist environmental conditions of the PPN and those which exist today raise doubts regarding the suitability of Southwest Asian villages as comparative ethnographic examples for PPN villages.

The favourable conditions that existed during the early Holocence are generally considered to have facilitated one of the greatest transitions in human history: the NDT from mobile hunter-gatherer to sedentary agro-pastoralist communities (Bar-Yosef 1998; 2000). This transitional period is further detailed in Chapter 3.

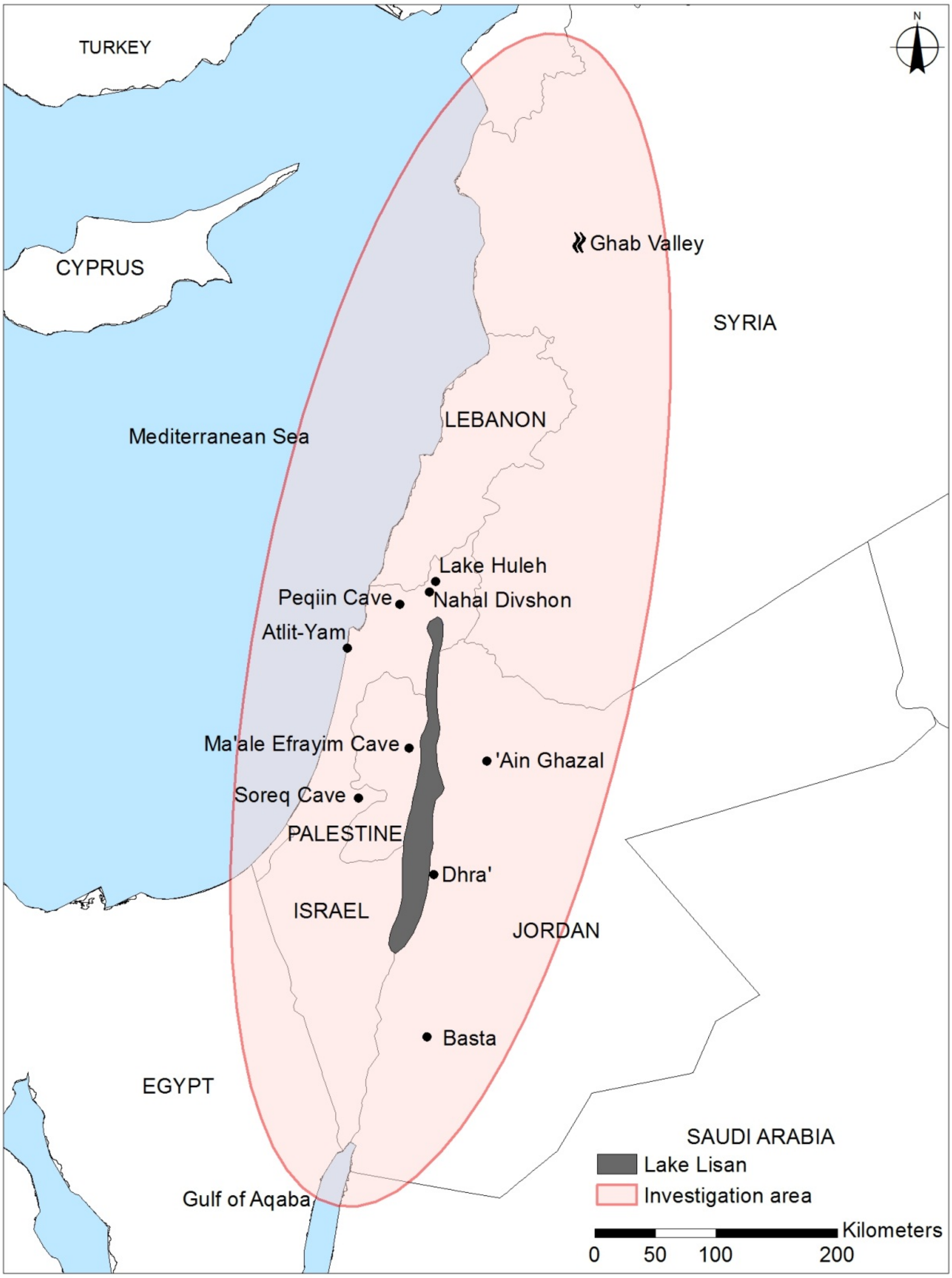


Figure 2.8. Palaeoclimate proxy sites and Palaeolithic sites and regions mentioned in the text (administrative boundaries from GADM Version 1, 2009).

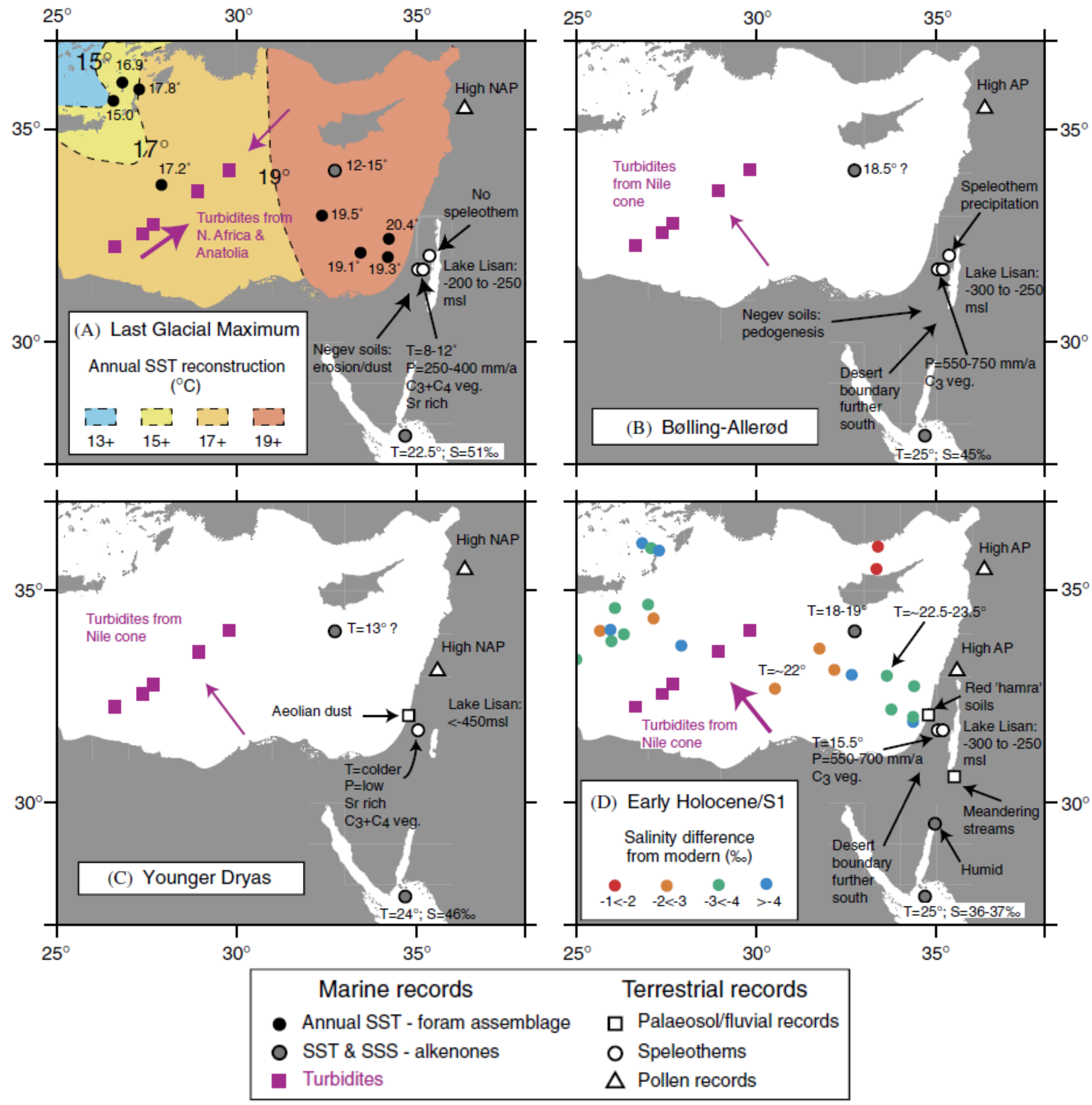


Figure 2.9. Climatic data summarised by Robinson *et al.* 2006 (p.1535) showing climatic conditions from the LGM to the early Holocene. Estimations based on turbidite data, Alkenone sea surface temperature (SST) and sea surface salinity (SSS) data, speleothem data, pollen data, lake levels, foraminiferal assemblages, sea surface salinity values, palaeosol data, fluvial data and temperature, precipitation and pollen maps drawn with open source Genetic Mapping Tools (GMT) available at http://gmt.soest.hawaii.edu.

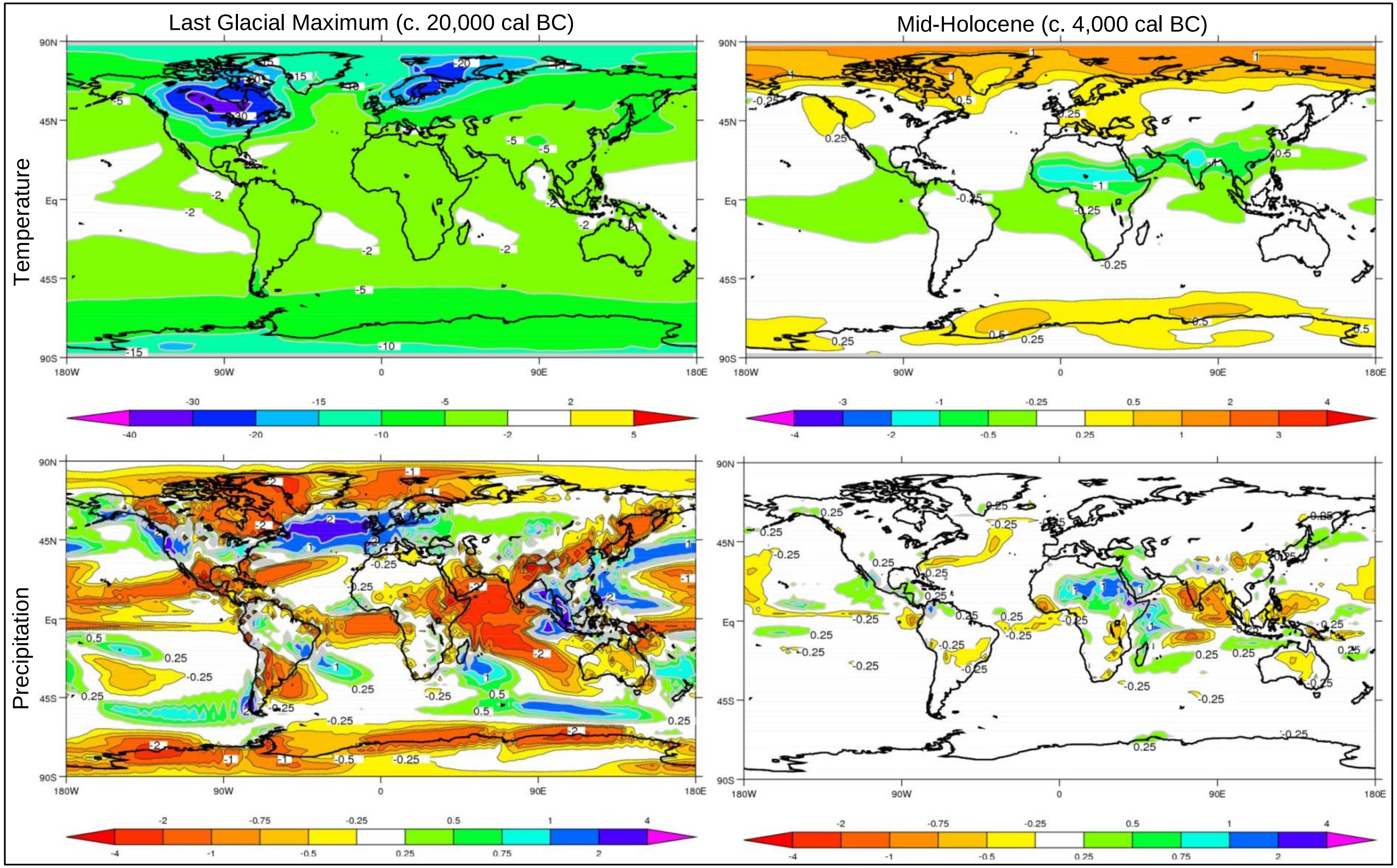


Figure 2.10. Difference in temperature and precipitation between the present and 1) the Last Glacial Maximum (LGM) (c. 20,000 cal BC); and 2) the mid-Holocene (c. 4,000 cal BC). LGM: average annual temperature c. 2-5°C lower and average daily precipitation up to c. 0.5 mm lower in the south and higher in the north. Mid-Holocene: average annual temperature up to 0.5°C higher in the north and average daily precipitation 0.25-0.75 mm higher (PMIP 2 2008a-d).

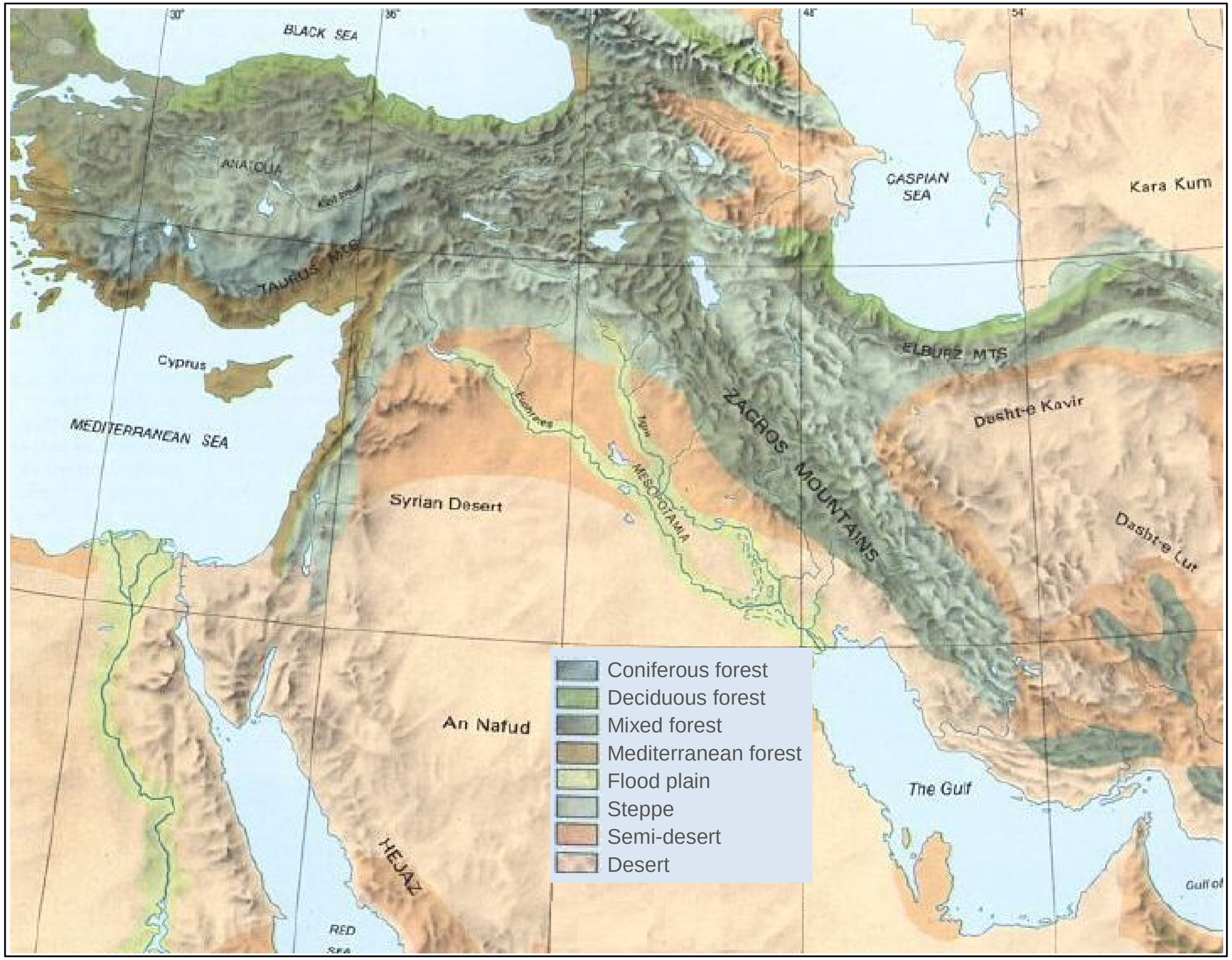


Figure 2.11. Vegetation reconstruction during the Neolithic (adapted from University of Oregon n.d.).

3 The Archaeological Background

The archaeological record of the central and southern Levant extends far back into the Pleistocene. The majority of archaeological research explores socio-cultural developments since the Epipalaeolithic period, from the end of the Last Glacial Maximum (c. 20,000 cal BC). A common theme of investigation is the widespread transition to sedentary subsistence strategies and the development of early villages during the Pre-Pottery Neolithic (PPN). This chapter summarises the chronological sequence for the PPN and information relating to village development throughout each PPN period.

3.1 The chronology

The PPN was originally identified by Kenyon (1956, pp.72-76), whose excavations at Jericho exposed settlement evidence comparable to Neolithic sites in the region, though devoid of pottery. Kenyon (1956) identified two distinct PPN phases. Subsequent investigations refined the time-stratigraphic, cultural-historical sequence (Goring-Morris and Belfer-Cohen 1997; Henry 1998; Garrard *et al.* 1999; Aurenche *et al.* 2001; Kuijt and Goring-Morris 2002; Byrd 2005b; Asouti 2006). Despite some debate, archaeologists generally propose three main PPN periods (PPN A, B and C), with a further three sub-periods within the PPNB (Early, Middle and Late) (Figure 3.1).

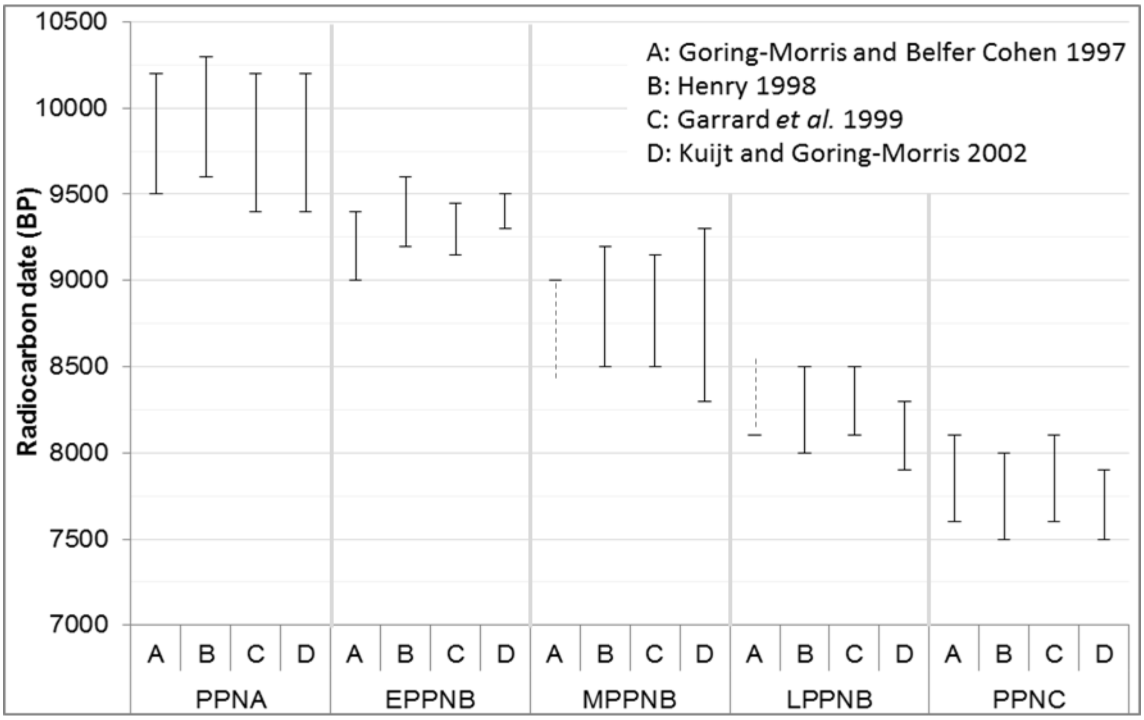


Figure 3.1. Various chronological sequences for the Pre-Pottery Neolithic (PPN) in the central and southern Levant. Dashed lines indicate M-LPPNB span. Goring-Morris and Belfer-Cohen (1997) use ‘Final PPNB’ instead of ‘PPNC’.

Cultural-historical schemes facilitate regional comparisons of broadly contemporaneous sites. The chronological precision of such schemes is critical for reconstructing population dynamics. The application of radiocarbon (^{14}C) dating techniques and the use of increasingly accurate calibration curves have enhanced this precision. Therefore, the commonly published radiocarbon ages (BP) for the PPN periods (based on Kuijt and Goring-Morris 2002, p.366) were calibrated in this investigation using the latest version of OxCal (v4.2.4) (Bronk Ramsey 2009) and the currently accepted IntCal13 atmospheric curve (Reimer *et al.* 2013). Date ranges are based on mid-point values of the 95% probability ranges (Table 3.1).

Table 3.1. Chronology of the Pre-Pottery Neolithic (PPN) in the central and southern Levant based on Kuijt and Goring-Morris (2002, p.366). Dates calibrated into Cal BP and Cal BC in OxCal v4.2.4 (IntCal13; based on mean 95% probability values) (Bronk Ramsey 2005; Reimer *et al.* 2013).

Period		**Radiocarbon date**		
		BP	*Cal BP*	*Cal BC*
PPNA		10200-9500	11900-10700	10000-8800
PPNB	Early	9500-9300	10700-10500	8800-8600
	Middle	9300-8300	10500-9300	8600-7400
	Late	8300-7900	9300-8700	7400-6700
PPNC (Final PPNB)*		7900-7500	8700-8300	6700-6400

* Contested term: 'PPNC' utilised by Rollefson and Köhler-Rollefson (1989) and Galili *et al.* (2004); 'Final PPNB' utilised by Goring-Morris and Belfer-Cohen (1997) and Barzilai (2013).

3.2 Pre-Pottery Neolithic A

The Pre-Pottery Neolithic A (PPNA) (c. 10,000-8,800 cal BC) is characterised by technological and typological variability in lithic assemblages between the northern and southern regions of the Levant, indicating potentially distinct cultural-historical phases and/or units (Edwards *et al.* 2004). The period is often divided into two phases: Sultanian and Khiamian, based on the frequencies of microliths and el-Khiam points in the Lower Jordan Valley (Crowfoot-Payne 1976; Kuijt and Goring-Morris 2002). However, as distinctions between these units remain unclear, the PPNA is treated as a single cultural entity in this research.

The climatic shift from the cold and dry conditions of the Younger Dryas to the warm and moist conditions of the early Holocene coincides with the beginning of the PPNA. Improved environmental conditions may have counteracted the need for residential mobility in response to seasonal resource availability. In resource rich areas with perennial water sources, some groups established permanent settlements that have been interpreted as formative villages (Goring-Morris and Belfer Cohen 1997, p.83) (Figure 3.2). These villages reached a maximum known extent of three hectares (Simmons 2007) and contained durable, curvilinear and often semi-subterranean structures of pisé and stone walls, such as at Dhra' (Kuijt 2001), Netiv Hagdud (Bar-

Yosef 1998), Zahrat adh-Dhra' 2 (Edwards *et al.* 2004; Edwards and House 2007) and Nahal Oren (Goring-Morris and Belfer-Cohen 2013) (Figure 3.3, A).

The improved environmental conditions provided a greater variety of resources, including small and medium mammals, reptiles, fish and birds (Kuijt and Goring-Morris 2002). Some groups developed new technologies to take advantage of these opportunities. Notched projectile points of various styles (i.e. el-Khiam, Jordan Valley and Salibiya), and arrow barbs and points formed from Hagdud and Gilgal truncations were produced in large quantities (Nadel *et al.* 1991) (Figure 3.3, B). More recent evidence suggests that Hagdud and Gilgal truncations were utilised as hafted micro-scrapers (Sayej 2005) and el-Khiam points as perforators (Smith 2005) for processing soft materials, such as leather. Large bifacially-retouched tools with sharp cutting edges developed into complex forms, including picks, adzes, axes and sickle blades hafted in large bone or wooden handles (Barkai 2011). Experimental archaeology conducted at Dhra' indicated that sickle blades may have been intensively utilised for harvesting wheat and barley (Goodale *et al.* 2010). High frequencies of ground stone implements including cup-hole mortars and pestles indicate extensive processing of these grains and a desire to extract the maximum nutritional value (Wright 1993). Cultivation, harvesting and processing of wild plant forms during the PPNA ultimately led to fully domesticated plant forms by the MPPNB (Kuijt and Goring-Morris 2002; Nesbitt 2002; Verhoeven 2004; Fuller *et al.* 2011).

Harvesting of storable food resources enabled communities to sustain their daily needs and to provide surplus for periods of seasonal or yearly shortage. The PPNA provides the most conclusive evidence for the commencement of surplus management in the form of storage facilities (Kuijt 2008a). There is evidence for small storage pits or bins in many structures, whilst other structures appear to have been built primarily for storage purposes, as at Dhra' (Finlayson *et al.* 2003; Kuijt and Finlayson 2009), Netiv Hagdud (Bar-Yosef and Gopher 1997), Jericho (Kuijt and Goring-Morris 2002) and possibly Wadi Faynan 16 (WF16) (Mithen *et al.* 2011; Finlayson *et al.* 2012) (Figure 3.3, C). At Dhra', storage structures with mud-plaster flooring and pisé-lined walls were suspended on timber floors supported with stone slabs. These were internally compartmentalised and exhibit cyclical stages of construction, use and abandonment. The central location of these storage features may indicate the communal nature of resource exploitation and distribution (Finlayson *et al.* 2012). This has been interpreted as representing a generally egalitarian society (Bar-Yosef 1998; Kuijt and Goring-Morris 2002; Finlayson *et al.* 2010, 2011, 2012).

The presence of storage systems reflects the emergence of a delayed-return economic system, whereby the yields of labour are held, managed and utilised over the following months and years (Woodburn 1982, pp.432-433). This had far-reaching implications for social organisation, potentially resulting in hierarchical ranking whereby some community members may have exerted control over resources and labour. In addition, surplus management enabled strengthening and enlargement of existing trade and exchange networks, for example, the obsidian trade from Anatolia to the southern Levant (Sherratt 2005). The need to manage more intricate and extended networks may be associated with the increased incidence of ritual and symbolic elements, including incised pebbles and human figurines (Kuijt and Chesson 2005; Edwards 2007), and monumental communal structures, such as the tower at Jericho (Finlayson *et al.* 2011) (Figure 3.3, D-F).

Although mortuary evidence generally indicates a standardised treatment of adult and child burials, including both primary and secondary burials, and a general lack of grave goods (Kuijt 1996), more recent evidence has revealed increasingly diverse burial practices. These include the presence of ground stone grave goods (Malinsky-Buller *et al.* 2013) and the association of skeletal remains with architectural elements, including the placement of burials within the Jericho tower and child burials under the post holes or walls of houses (Kuijt and Goring-Morris 2002, p.378) (Figure 3.3, F). The association of skeletal remains with houses has been interpreted as representing more sedentary communities, who sought to create permanent links between themselves, their dwellings, their land and their ancestors (Watkins 1992).

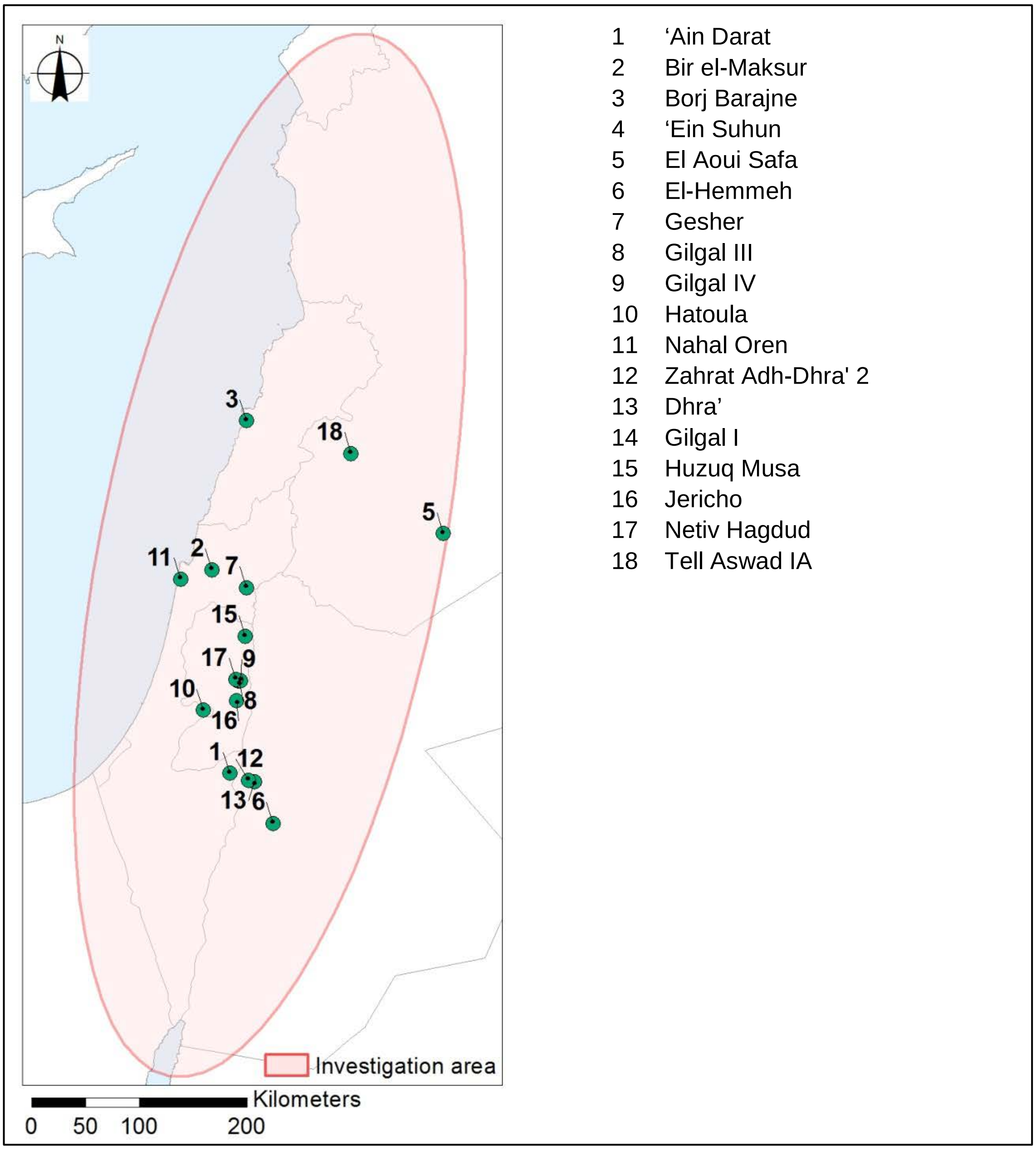


Figure 3.2. Distribution of PPNA villages in the current database. ID numbers correspond to those within the PPN village database (Appendix D.1).

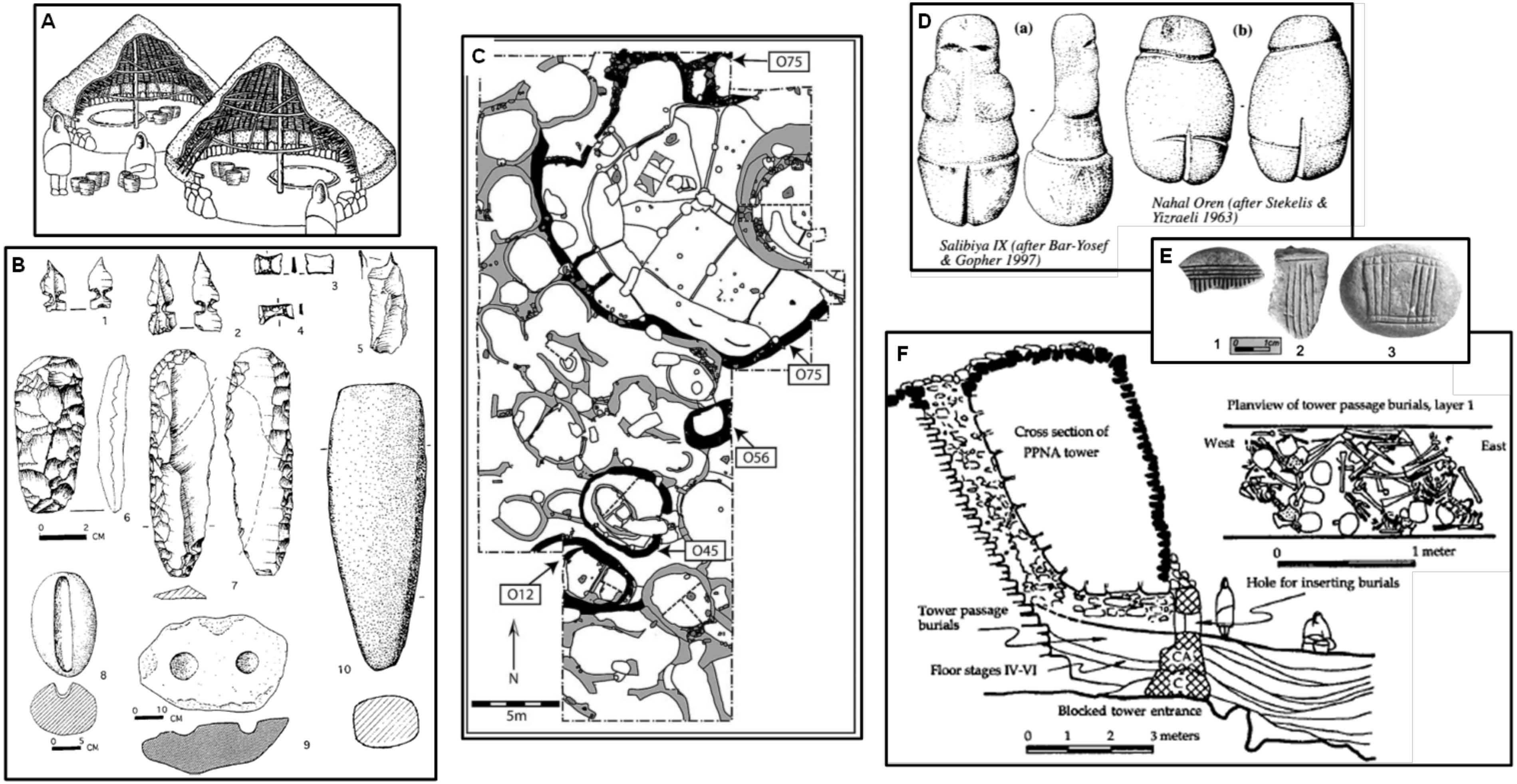


Figure 3.3. PPNA archaeological features. A: residential structure schematic (Kuijt and Goring-Morris 2002, p.375); B: tool assemblage - el-Khiam points (1/2), Hagdud truncations (3/4), awl (5), bifacial axe (6), sickle blade (7), shaft straightener (8), cup holed limestone slab (9), limestone celt (10) (Bar-Yosef 1998, p.171); C: Wadi Faynan 16 (WF16) - plan of excavated area with large communal structure (O75) and potential storage structures (O12 and O45) (Finlayson *et al.* 2012, p.19); D: figurines (Kuijt and Chesson 2005, p.159); E: incised stones from Zahrat adh-Dhra' 2 (Edwards 2007, p.29); F: Jericho Tower (Kuijt and Goring-Morris 2002, p.375).

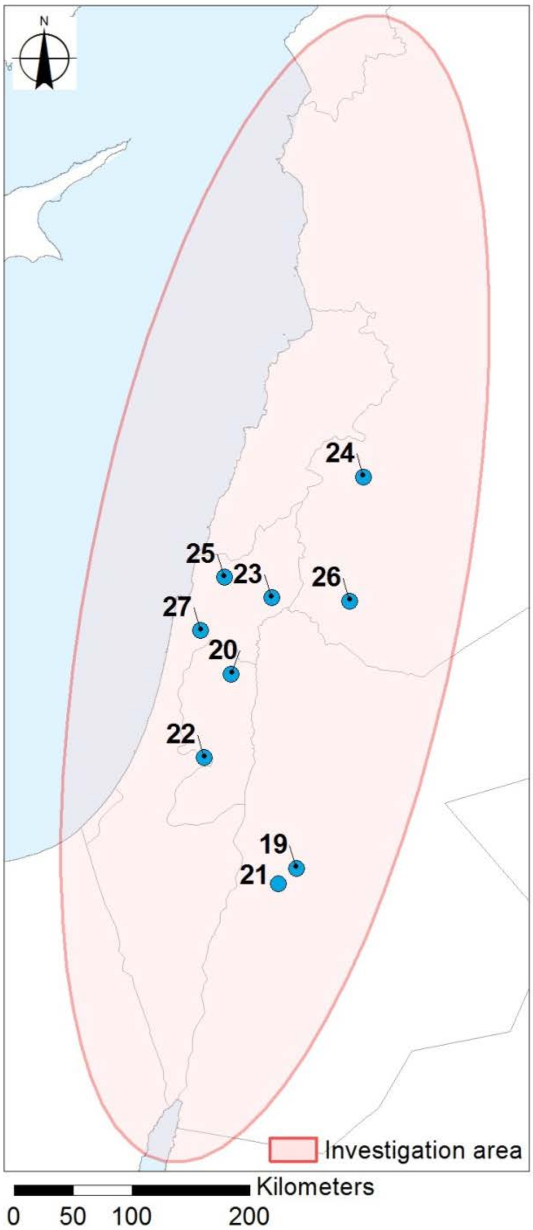
3.3 Early Pre-Pottery Neolithic B

The Early Pre-Pottery Neolithic B (EPPNB) (c. 8,800-8,600 cal BC) represents a transitional period between the socio-cultural and economic systems of the PPNA and the MPPNB. The limited evidence for continuity in these systems between many PPNA and MPPNB sites may indicate that this was a relatively rapid transformation (Kuijt 1997; Edwards and Sayej 2007). Knowledge of this period is limited, particularly in more southern regions of the Levant, where few settlements have undergone detailed investigation (Figure 3.4). This has ignited debate about the existence and extent of this cultural-historical period in this region (Gopher 1996; Kuijt and Goring-Morris 2002).

Current evidence suggests that the EPPNB originated along the Euphrates in North Syria at sites such as Mureybet III, Dja'de al-Mughara, Cheikh Hassan and Jerf al-Ahmar. Debate continues as to the origin of EPPNB occupation in the central and southern Levant. Some argue that the EPPNB independently emerged in this region, whilst others suggest the migration of ideas and/or people from the north, based on the abundance of non-local, fine-grained material, such as Anatolian obsidian and chalcedony (Edwards *et al.* 2004; Khalaily *et al.* 2007).

EPPNB settlement represents the beginnings of the transition from curvilinear to rectilinear architectural forms (Figure 3.5, A) (Khalaily *et al.* 2007; Balbo *et al.* 2012). These architectural developments, as well as the use of lime plaster flooring and evidence for cleaning activities have been interpreted as reflecting longer term occupation (Kuijt and Goring-Morris 2002). There is some evidence for permanent internal storage facilities (i.e. at Motza), although the lack of excavated sites makes it difficult to make general statements about the degree and success of food procurement strategies and related aspects of social organisation (Khalaily *et al.* 2007). However, current evidence suggests increasing manipulation of wild cereals resulting in the domestication of wheat, barley and lentils as part of a low-level food production economy (Kuijt and Goring-Morris 2002; Byrd 2005b; Asouti and Fuller 2013).

A major characteristic of the EPPNB is the predominance of Helwan points amongst other flint projectile forms such as Jericho, Byblos and Amuq types (Edwards and Sayej 2007; Gopher 1994; Edwards *et al.* 2004) (Figure 3.5, B). This changing technology highlights aspects of economic and social development. For example, craft specialisation is indicated by innovative tool technology (i.e. naviform core reduction), which enabled systematic production of relatively uniformly-shaped, parallel-sided blades utilised as sickles, arrowheads, borers and perforators (Kuijt and Goring-Morris 2002) (Figure 3.5, C). In addition, a decreasing presence of perforating tools infers different strategies for material manipulation (Khalaily *et al.* 2007). Further, the increasing use of lime plaster for flooring and its application to the treatment of human remains prior to burial demonstrates significant investment in secondary resource production (Gopher 1994; Edwards *et al.* 2004). These experimentations with different tool types and technologies required specialist knowledge and facilitated more standardised and specialised outputs.



19 ‘Ain Abu Hudhud
20 Ein Suhun
21 El Hemmeh
22 Motza VI
23 Mujahiya
24 Tell Aswad IB
25 Horvat Galil
26 Tell Qarassa
27 Mishmar Ha’emeq

Figure 3.4. Distribution of EPPNB villages in the current database.

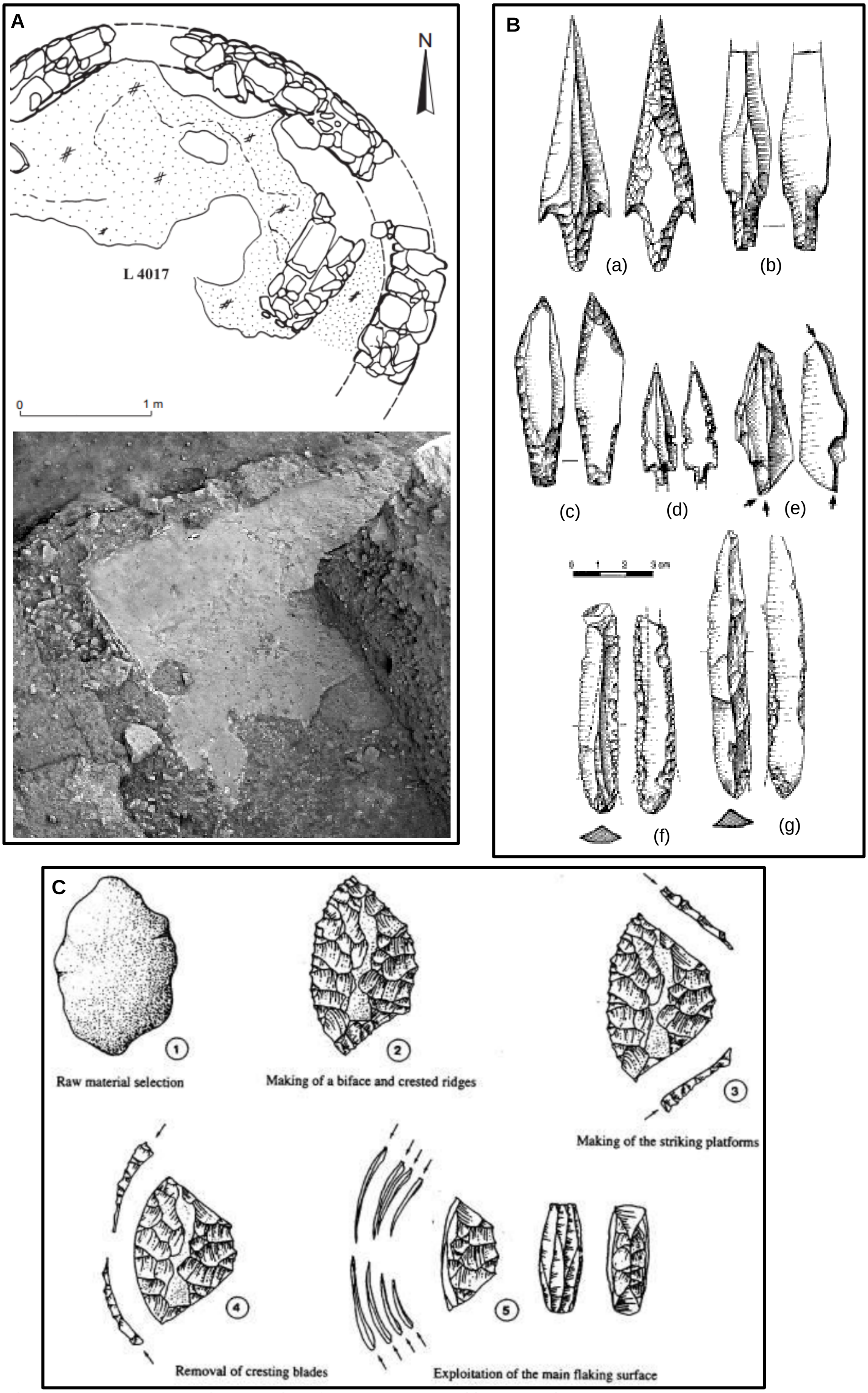


Figure 3.5. EPPNB archaeological features. A: curvilinear and rectangular structures at Motza (Khalaily *et al.* 2007, pp.9-10); B: tools - Jericho point (a), Byblos point (b), Amuq point (c), Helwan point (d), burin (e), sickle blades (f/g) (adapted from Kuijt and Goring-Morris 2002, p.401); C: model of naviform core reduction sequence (Nishiaki 2000, p.56).

3.4 Middle Pre-Pottery Neolithic B

There is extensive archaeological evidence for the Middle Pre-Pottery Neolithic B (MPPNB) period (c. 8,600-7,400 cal BC) from sites such as Beidha (Kirkbride 1966; Byrd 2005a), Jericho (Kenyon 1981), ‘Ain Ghazal (Rollefson *et al.* 1992), Ghwair I (Simmons and Najjar 2006) and Shkārat Msaied (Hermansen *et al.* 2006) (Figure 3.6). MPPNB archaeological evidence is often utilised to generalise the broader PPNB period, misrepresenting the vast differences in social, economic, technological and ritual characteristics of the Early, Middle and Late PPNB (Kuijt and Goring-Morris 2002) (Figure 3.7).

Numerous settlements were established in the Mediterranean zone along the eastern foothills and in the centre of the Jordan Valley, indicating relatively rapid regional population growth. Marginal arid zones were more intensively exploited during this period, possibly as a result of population pressure (Hole 1984). The colonisation of more arid zones enlarged the interaction sphere of MPPNB communities, facilitating (and perhaps necessitating) greater exchange of goods between core and peripheral zones and between communities engaged in variable production activities (Wright and Garrard 2003).

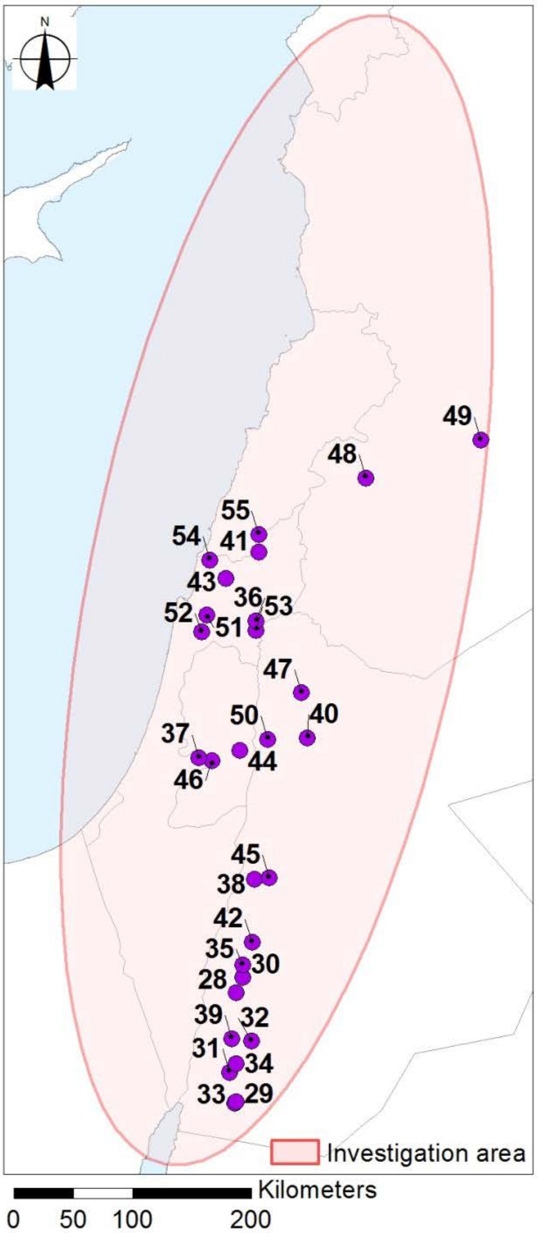
MPPNB villages represent small- to medium-sized communities. Those in more marginal and transitional environments (i.e. ‘Ain Abu Nekheileh, Beidha and Shkārat Msaied) occupied small areas (< 0.5 ha), whilst those in the central Jordan Valley and further north (i.e. ‘Ain Ghazal, Beisamoun, Jericho and Tell Aswad II) were larger (c. 4-5 ha). These larger villages may have maintained regional economic, ritual and social functions. However, the degree of autonomy of smaller settlements and the economic importance of larger settlements remains debated (Kuijt and Goring-Morris 2002; Simmons and Najjar 2006).

MPPNB settlements demonstrate considerable regional variability in terms of subsistence strategy, settlement structure and organisation. In more marginal, arid zones, hunter-gatherer subsistence strategies are evidenced by higher percentages of projectile points and burins (Garrard *et al.* 1994; Bar-Yosef 1998; Betts 1998; Kuijt and Goring-Morris 2002). These settlements usually comprised clusters of curvilinear, often semi-subterranean, mud and stone-walled structures, as at Beidha and Shkārat Msaied (Kirkbride 1966; Byrd 2005a; Hermansen *et al.* 2006; Kinzel 2013) (Figure 3.7, A). Settlements in central areas practiced more sedentary food procurement strategies, including cultivation of a wide repertoire of plants, such as wheat, barley, flax, peas, lentils, chickpeas, figs, almonds and pistachios (Rollefson *et al.* 1992; Simmons and Najjar 1998; Colledge 2001; Colledge and Conolly 2007; Stordeur and Jamous 2009; Weiss and Zohary 2011). Incipient pastoral practices involved the exploitation of ovicaprines for meat and potentially milk and wool, as at ‘Ain Ghazal (Wasse 2002). These villages often comprised more durable, rectilinear, sometimes multi-storey structures (i.e. ‘Ain Ghazal, Beisamoun, Jericho and Wadi Shu’eib) (Goring-Morris and Belfer-Cohen 2008; Guerrero *et al.* 2009) (Figure 3.7, B-D). Similar architectural features did not appear in marginal zones for another several hundred years.

Residential structures usually exhibit standardised form and size within settlements. These were often internally partitioned with an entrance at one end opening onto an internal space with a central hearth (Goring-Morris and Belfer-Cohen 2013). The simple and modestly-sized nature of residential buildings, many of which contain private storage facilities, supports the interpretation that the household was the fundamental socio-economic unit of MPPNB societies (Banning 2003). At the same time, communal or non-residential architecture also became more discernible. This is evident at Beidha (Byrd 1994; 2005a), Mishmar Ha’emeq (Barzilai and Getzov 2008), Munhata (Kuijt and Bar-Yosef 1994) and Wadi Hamarash I (Sampson 2013a). These structures were usually centrally located and larger than residential structures, with different morphology, more superior construction and more elaborate decoration.

Larger settlements with higher structural density indicate increased population sizes and higher population densities that would have required new strategies for community cohesion. An effective strategy for this is the establishment of formalised ritual practices. MPPNB ritual beliefs represent a consolidation of a wide range of ritual practices and symbolic items. Household-based ritual practices may even be evident at Shkārat Msaied, which contained regularly located platforms within houses (Kinzel 2013) (Figure 3.7, A). Human skeletal remains were increasingly associated with residential architecture, including both primary and secondary burials beneath house floors and in courtyard areas (Kuijt and Goring-Morris 2002) (Figure 3.7, D). There was extensive skull removal, with skulls sometimes plastered or painted and reburied in individual or multiple caches. Lime plaster-modelling and asphalt coating of skulls provided life-like representations, which have been linked to ancestor worship and communal festive activities (Arensburg and Hershkovitz 1989; Goren *et al.* 2001; Kuijt 2008b). Large plaster anthropomorphic figurines (c. half-life size) were found at ‘Ain Ghazal (Rollefson 1983) and life-size limestone masks with inset eyes were found at Jericho (Kenyon 1981) (Figure 3.7, E). Plaster was also utilised for ritual representations of animals, particularly cattle, reflecting increasing interactions between humans and these animals. Small clay cattle figurines, some showing evidence of ritual slaughter using flint prior to setting, have been interpreted as representing cattle cult practices (Rollefson 2008) (Figure 3.7, F).

The presence of plaster-manufacturing facilities in residential areas, and the extensive evidence for lime plaster products, indicate the importance of plaster for both residential (i.e. wall and floor coating) and non-residential (i.e. ritual items) purposes. This production required such extensive exploitation of wood resources for fuel that it may have induced local deforestation around settlements. Rollefson and Köhler-Rollefson (1989, p.79) estimated that over the total period of settlement at ‘Ain Ghazal (c. 1,500 years), almost 43,000 trees were felled across 3,268 hectares for plaster manufacture. Lime plaster production requires considerable labour input and specialist knowledge, providing some of the earliest evidence for craft specialisation and large-scale secondary production within PPN villages. In more marginal zones, locally-available materials were also exploited, for example, for large scale bead production at Jebels Arqa, Rabigh, Ragref and Salaqa (Fabiano *et al.* 2004; Wright 2008).



28 Adh-Dhaman I
29 ‘Ain Abu Nekheileh
30 Beidha
31 Jebel Arqa
32 Jebel Rabigh
33 Jebel Ragref
34 Jebel Salaqa
35 Shkārat Msaied
36 Tell Eli IV (Khirbet Sheikh Ali)
37 Abu Gosh
38 Wadi Hamarash I
39 ‘Ail IV
40 'Ain Ghazal
41 Beisamoun
42 Ghwair I
43 Horvat Galil
44 Jericho
45 Khirbet Hammam
46 Motza V
47 Tell Abu es-Sawwan
48 Tell Aswad II
49 Tell Ghoraifé I
50 Wadi Shu'eib
51 Yiftah'el IV
52 Mishmar Ha’emeq
53 Munhata IV-VI (Horvat Minha)
54 Nahal Betzet I
55 Tel Roim West V

Figure 3.6. Distribution of MPPNB villages in the current database.

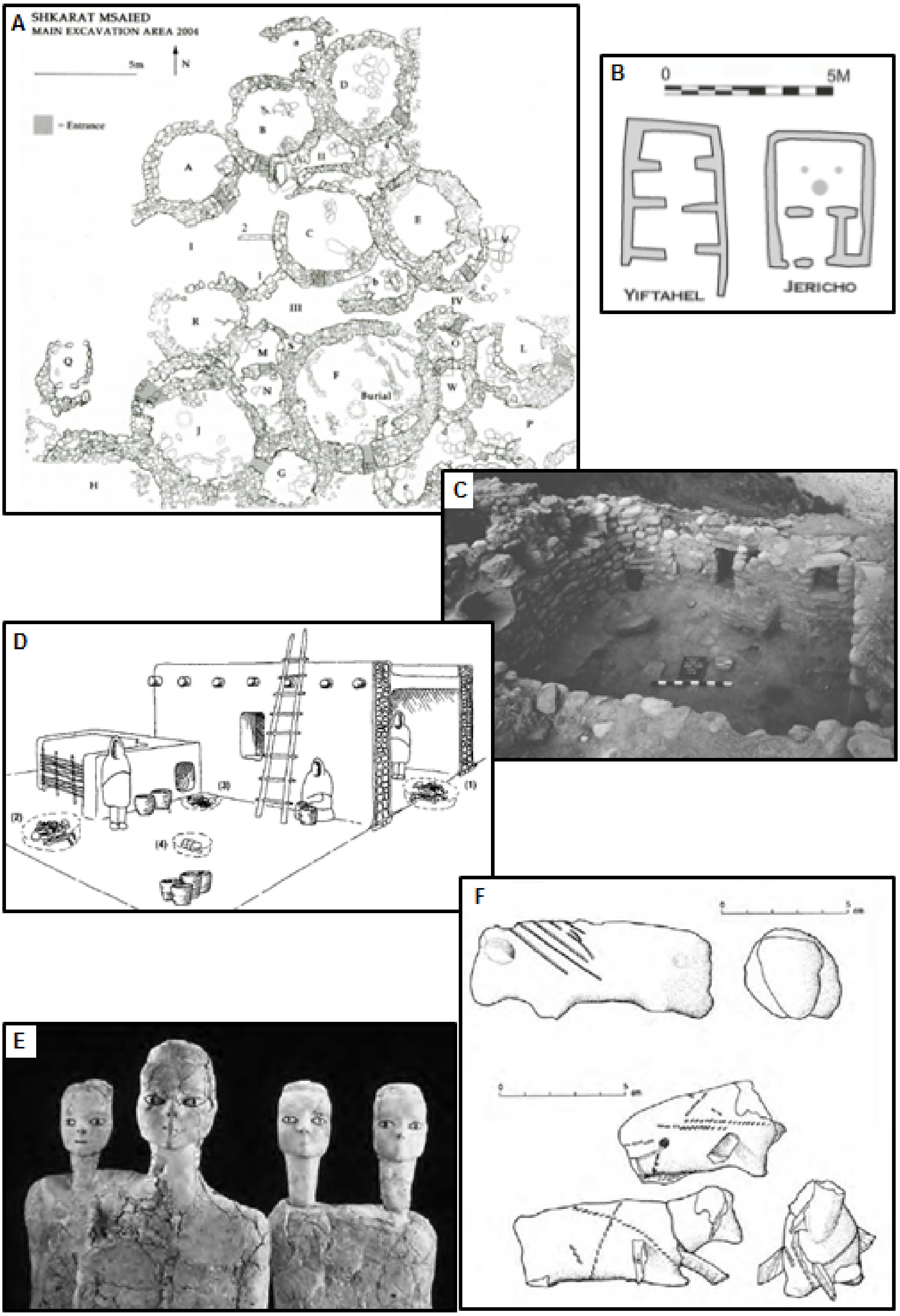


Figure 3.7. MPPNB archaeological features. A: site plan of Shkārat Msaied (Jensen *et al.* 2005, p.115); B: pier or corridor house forms - buttresses often interpreted as representing basements of two-storey structures (Goring-Morris and Belfer-Cohen 2013, p.27); C: rectangular room with niches and bins at Ghwair I (Simmons and Najjar 2006, p.81); D: mortuary practices associated with residential architecture (Kuijt and Goring-Morris 2002, p.390); E: lime plaster anthropomorphic figurines from ‘Ain Ghazal (Rollefson 2008, p.402); E: cattle figurines from ‘Ain Ghazal (Rollefson 2008, p.399).

3.5 Late Pre-Pottery Neolithic B

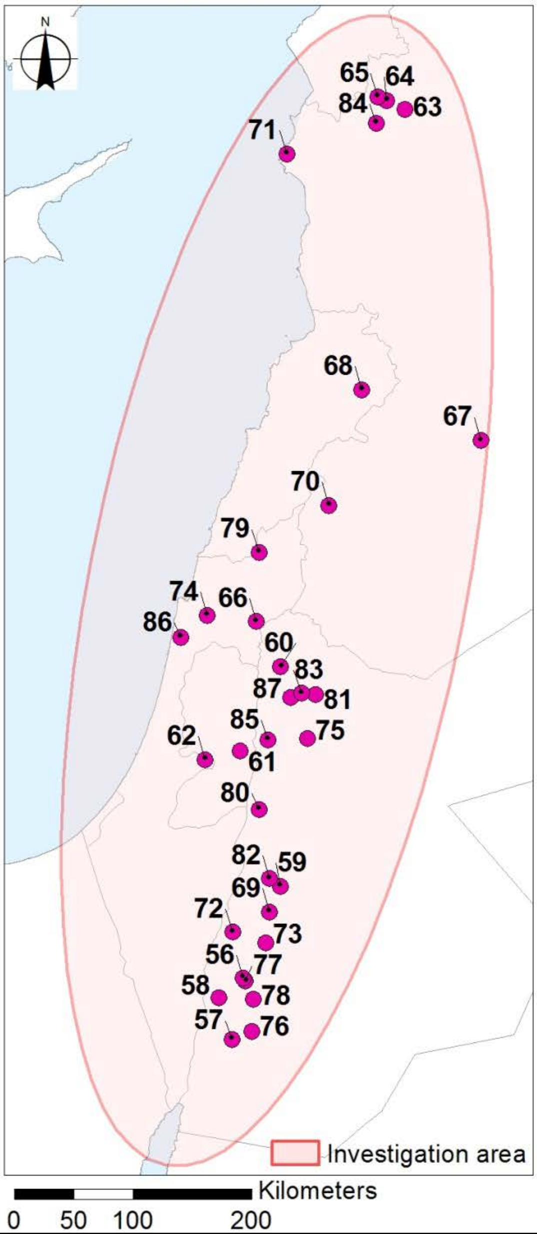
During the Late Pre-Pottery Neolithic B (LPPNB) (c. 7,400-6,700 cal BC) evidence suggests frequent abandonment of MPPNB settlements in the western Mediterranean zone and the central Jordan Valley, with relocation to new and pre-existing settlements in more arid regions to the east (Byrd 1992; Garrard *et al.* 1994; Kuijt and Goring-Morris 2002) (Figure 3.8). West of the Jordan Valley, few sites (i.e. Beisamoun and Tell Eli) demonstrate continuity between the MPPNB and LPPNB. In the east, continued occupation of MPPNB sites gave rise to very large villages (> 7 ha), often termed "mega-sites", such as 'Ain Ghazal, Tell Abu es-Sawwan and Wadi Shu'eib (Rollefson 1989a; Gebel 2004a; Al-Nahar 2006). Numerous new settlements were established in previously unoccupied areas suggesting massive regional population growth and expansion. These included large settlements at 'Ain Jamam, Basta and es-Sifiya (Kuijt and Goring-Morris 2002; Goring-Morris and Belfer Cohen 2008).

The impetus for an easterly shift may have been a combination of factors, including environmental degradation, population pressure and resource stress. By the LPPNB, settlements relied largely on agro-pastoralist practices, with evidence suggesting that almost 80% of the meat diet was sourced from domesticated animals, including goat, sheep, pig and cattle (Twiss 2007, p.128; Makarewicz 2013; Martin and Edwards 2013). These intensive land use practices may have encouraged expansion into more marginal areas, requiring further developments in tool technology, water management and agro-pastoral practices adapted for more arid environments.

The majority of architecture during the LPPNB was rectilinear. The use of lime plaster for wall and floor coating decreased, possibly due to reduced availability of wood required for lime production (Rollefson and Köhler-Rollefson 1989; Kuijt and Goring-Morris 2002). Whilst unfired mud brick buildings remained common in the western regions, the availability and increased use of flat stones as a building material in the eastern regions enabled more complex architecture. Two-storey, enclosed 'courtyard' houses consisting of a series of small areas for storage on the lower floor and domestic activities on the upper floor were constructed at Beidha, es-Sifiya and possibly Basta (Byrd 2005a; Goring-Morris and Belfer-Cohen 2008) (Figure 3.9, A). Pueblo-style settlements, comprising closely-packed structures on steep slopes, appeared at Ba'ja and 'Ain Jamam (Gebel 2006; Goring-Morris and Belfer-Cohen 2008) (Figure 3.9, B). Increased architectural density and reduced incidence of freestanding structures within more eastern settlements (i.e. 'Ain Jamam, 'Ain Ghazal, Ba'ja, Basta, Beidha and es-Sifiya) suggest greater population densities in these areas (Kuijt 2000). The construction of sub-floor channels for water management or air ventilation at several sites, including el-Hemmeh, ‘Ain Jamam, es-Sifiya and Basta, may be evidence of strategies to cope with these higher population densities (Mahasneh 1996).

Non-residential structures continue to differ from residential structures in morphology, construction and associated features. For example, two curvilinear buildings at ‘Ain Ghazal have been interpreted as “temples” (Rollefson 1998a) (Figure 3.9, C). The first had red painted floors and sub-floor channels radiating from a central hole that may have been a hearth or “altar”. However, the use of standardised religious terminology, such as ‘temple’ and ‘altar’, has been questioned as this may induce interpretation of a more formalised ritual system than was actually the case (Goring-Morris and Belfer-Cohen 1997).

Evidence indicates the endurance of earlier PPNB ritual practices, although there appears to be a decline in the manufacture of skull masks and anthropomorphic figurines, possibly linked to a reduction in lime plaster production (Rollefson and Köhler-Rollefson 1989; Rollefson *et al.* 1992; Rollefson 2008). Burials continued to be associated with residential architecture, interred beneath house floors and in courtyards, with some evidence for skull caching and plastering. Grave goods became more prevalent and included shell necklaces, bracelets, stone beads, pendants and animal skeletal elements (Kuijt and Goring-Morris 2002) (Figure 3.9, D). It is argued that grave goods, particularly those made from imported materials, signify concern with identity and displays of status, potentially reflecting an increasingly hierarchical social system (Kuijt and Goring-Morris 2002). A more complex social system may also be evidenced by large quantities of geometric tokens and incised pebbles, which have been argued to reflect economic practices involving the transfer of goods and services (Mahasneh and Gebel 1998; Edwards 2007) (Figure 3.9, E).



56 Beidha
57 ‘Ail IV
58 Ba'ja
59 El Hemmeh
60 Er-Rahib (WY180)
61 Jericho
62 Motza Tahtit (Nahal Soreq)
63 Qminas
64 Tell Aray
65 Tell el-Ghafar I
66 Tell Eli III (Khirbet Sheikh Ali)
67 Tell Ghoraifé II
68 Tell Labwé
69 Tell Rakan I (WZ 120)
70 Tell Ramad I
71 Tell Ras Shamra V C
72 Tel Tif'dan (Wadi Fidan A)
73 Wadi Badda
74 Yiftah'el III
75 'Ain Ghazal
76 ‘Ain Jamam
77 Al-Baseet
78 Basta
79 Beisamoun
80 Es-Sifiya
81 Kharaysin
82 Khirbet Hammam
83 Tell Abu es-Sawwan
84 Tell 'Ain el-Kerkh/II
85 Wadi Shu'eib
86 Aviel
87 Es-Sayyeh

Figure 3.8. Distribution of LPPNB villages in the current database.

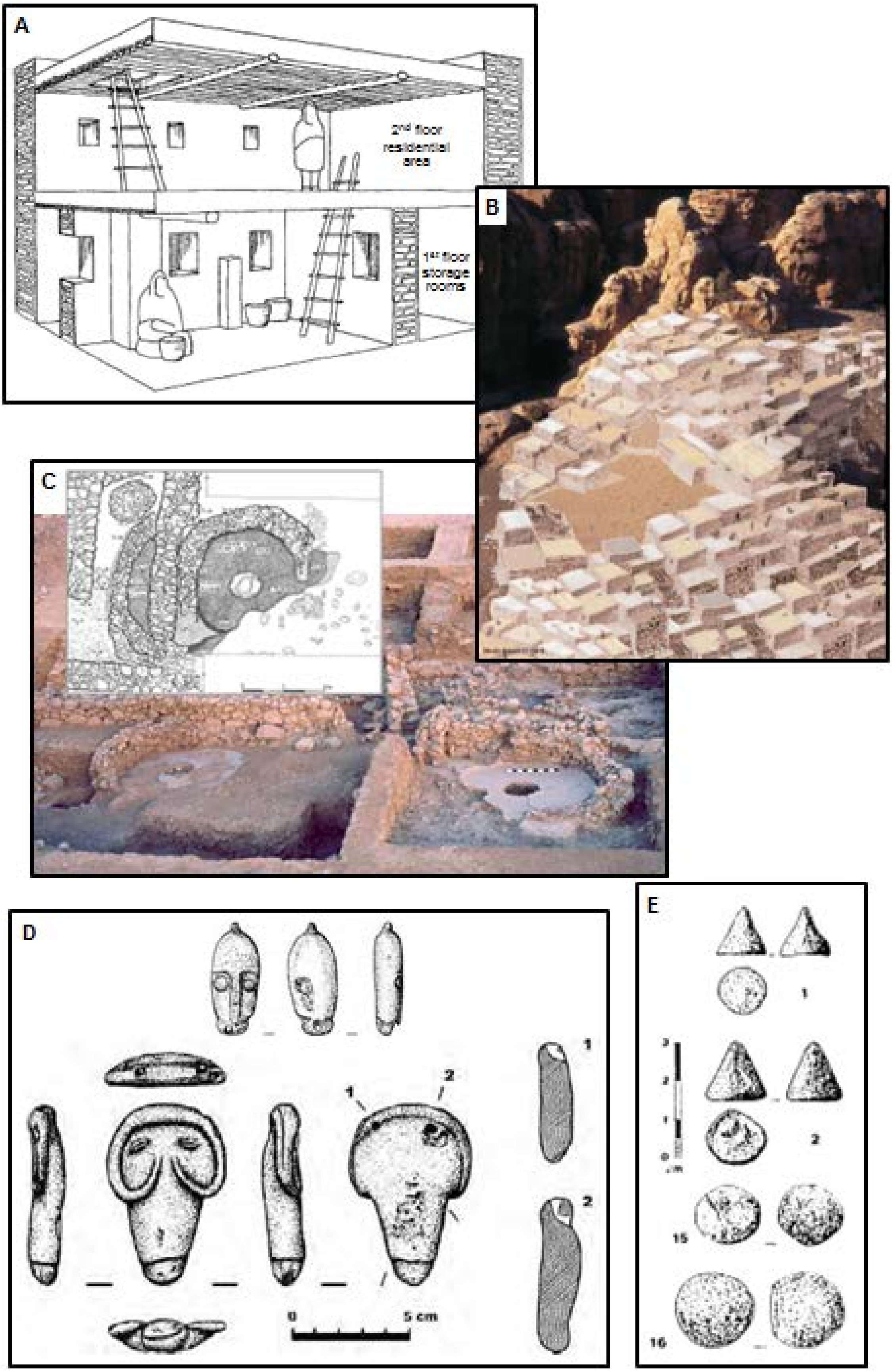


Figure 3.9. LPPNB archaeological features. A: schematic reconstruction of possible two-storey residential architecture at Basta showing storage facilities on the ground floor and open domestic space on the upper floor (Kuijt and Goring-Morris 2002, p.409); B: digital reconstruction of pueblo-style, steep slope settlement at Ba'ja (Gebel 2006, p.69); C: drawing and photograph of curvilinear "temples" at 'Ain Ghazal (Kafafi 2010, p.304); D: pendants from Basta (adapted from Rollefson 2008, p.407); E: geometric tokens from es-Sifiya - cones (1/2), spheres (15/16) (Mahasneh and Gebel 1998, p.108).

3.6 Pre-Pottery Neolithic C

For decades a gap in occupation of almost 1,000 years was documented between the end of the PPNB and the beginning of the Pottery Neolithic. However, the excavation of some archaeological sites with radiocarbon dates relating to this period has provided sufficient evidence for interim occupation, termed the Pre-Pottery Neolithic C (PPNC) (c. 6,700-6,400 cal BC) (Rollefson 1990; Rollefson *et al.* 1992; Rollefson and Köhler-Rollefson 1993) (Figure 3.10). These sites revealed various continuities and changes in settlement patterns, architecture, mortuary practices and lithic technology. Some researchers have interpreted the continuities as representing an extension of the PPNB rather than a new phase, preferring to label this period the Final Pre-Pottery Neolithic B (FPPNB) (Rollefson and Köhler-Rollefson 1993; Goring-Morris and Belfer-Cohen 1997; Barzilai 2013).

Limited archaeological evidence for the PPNC makes it difficult to generalise about this period. Although some new villages were established, for example, at Hagoshrim in the Huleh Valley and along the Mediterranean littoral zone at Atlit-Yam, there appears to be population contraction at the end of the LPPNB, with few sites demonstrating occupational continuity from the LPPNB to the PPNC (i.e. ‘Ain Ghazal, Wadi Shu’eib, and perhaps Basta, es-Sifiya, Yiftah'el, Tell Eli, Ramad and Beisamoun) (Kuijt and Goring-Morris 2002).

Limited excavation evidence, mainly from ‘Ain Ghazal, indicates increased reliance on foraging activities (Rollefson and Köhler-Rollefson 1993; Kuijt and Goring-Morris 2002). At ‘Ain Ghazal, the meat diet revolved around a small set of domesticated animals, particularly sheep with some goat, pig and cattle, with the latter two species also used for ritual practices (Kuijt and Goring-Morris 2002, p.417). Domestic sheep numbers increased rapidly during the PPNC. Age and sex data suggests primary focus on meat production rather than secondary products, such as milk and wool (Wasse 2002). Hunting activities remained an important strategy for supplementing the diet. This is evidenced by skeletal remains of wild gazelle and onager; the appearance of ‘desert kites’ interpreted as holding enclosures for large numbers of animals; and the proliferation of projectile points (Betts 1998, p.157; Kuijt and Goring-Morris 2002, p.417). Where lower frequencies of sickle blades exist, such as at ‘Ain Ghazal, this has been interpreted as representing harvesting of reeds in favour of cereals, although, there is continued cultivation of wheat, barley, legumes and flax at many settlements (Rollefson and Köhler-Rollefson 1993; Galili *et al.* 2004). Evidence suggests that coastal zones, in particular, maintained a wide spectrum subsistence economy based on a combination of agro-pastoralist, hunter-foraging and fishing activities that minimised the risks associated with seasonality and ecological conditions (Galili *et al.* 2004).

A great degree of effort was devoted to the construction of communal structures including semi-subterranean refuse dumps, water wells and large dividing walls (Figure 3.11, A-B) (Rollefson *et al.* 1992; Kuijt and Goring-Morris 2002). The presence of wells indicates theoretical knowledge and practical understanding of hydrological processes as well as specialised extraction and construction technology (Galili and Nir 1993).

Whilst immense effort was expended on communal structures, a limited degree of effort was expended on residential structures (Figure 3.11, C). Limited evidence for new construction indicates a preference for modification and reuse of earlier LPPNB buildings. Lime plaster flooring was replaced by crushed marl flooring and even where stones were available, mud brick constituted the main building material (Kuijt and Goring-Morris 2002).

Mortuary evidence suggests diverse burial practices involving a continuation of primary single and group burials, interment of infants in courtyard or open areas, occasional skull removal and burial with animal remains. At Wadi Shu'eib, primary burials are common (Simmons *et al.* 2001), whilst at 'Ain Ghazal there is increased incidence of secondary burial practices of the type often associated with more mobile communities, including isolated bones and incomplete skeletons (Rollefson 1998a). Ritual and symbolic items, such as anthropomorphic and animal figurines, and items of personal adornment made from marble, stone and mother of pearl indicate a continuation of existing ritual practices and social organisation (Kuijt and Goring-Morris 2002; Wright *et al.* 2008) (Figure 3.11, D).

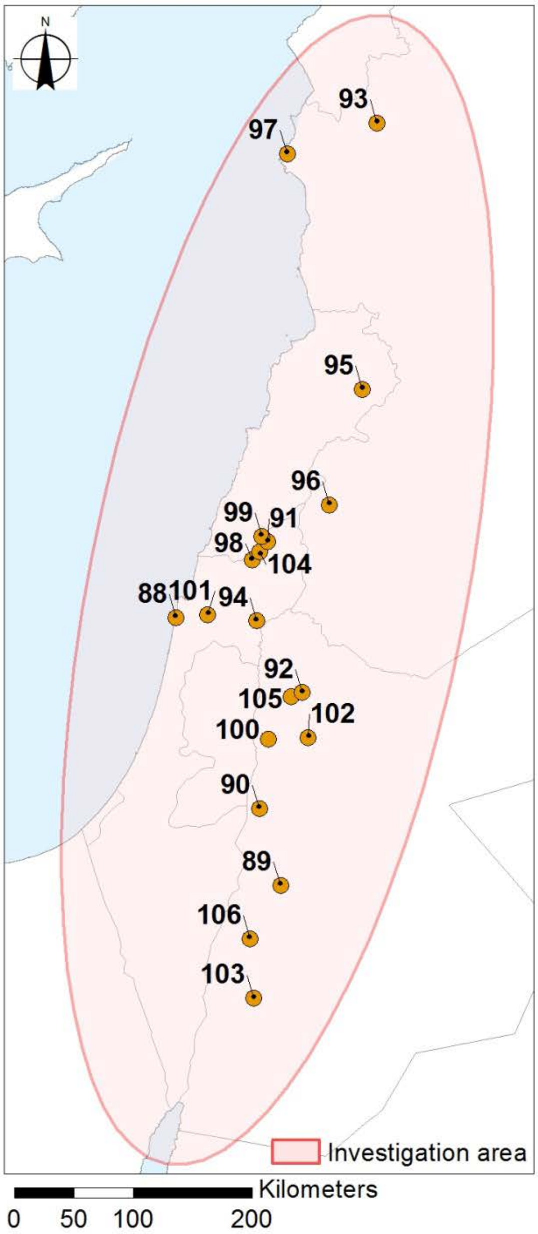


Figure 3.10. Distribution of PPNC villages in the current database.

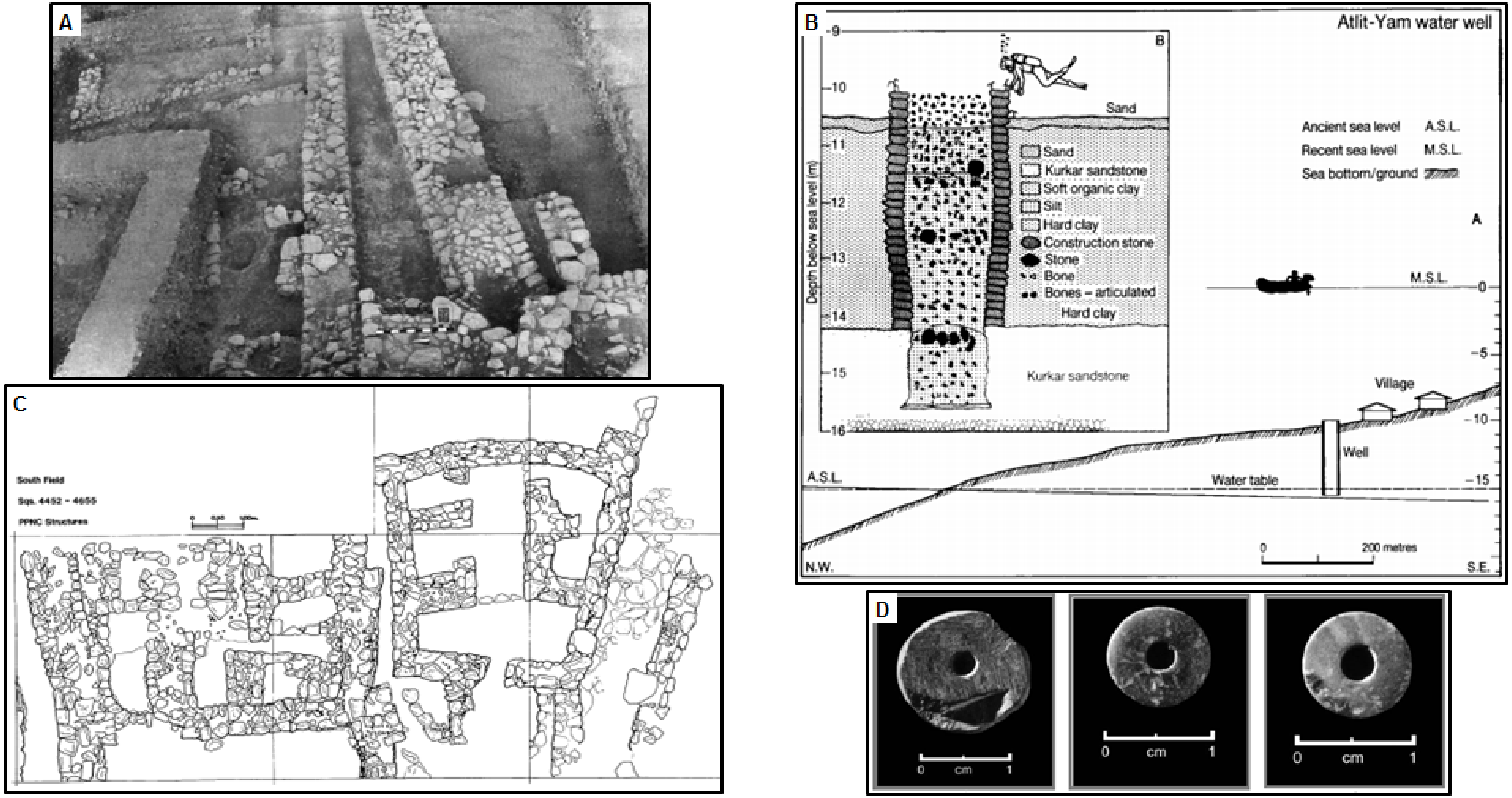


Figure 3.11. PPNC archaeological features. A: large walls constructed at ‘Ain Ghazal (Rollefson and Köhler-Rollefson 1993, p.38); B: schematic cross-section of a well at the coastal village of Atlit-Yam, showing location of the village in relation to ancient and modern sea levels (ASL and MSL) (Galili and Nir 1993, p.268); C: residential structures at ‘Ain Ghazal (Rollefson *et al.* 1992, p.451); D: disc beads of red dabba marble from Wadi Jilat 25 (Wright *et al.* 2008, p.144).

3.7 Summary of major developments

Archaeological evidence suggests that improved climatic conditions at the beginning of the Holocene facilitated the emergence of formalised village settlements during the PPNA (c. 10,000-8,800 cal BC). PPNA communities engaged in more diverse food procurement activities than their predecessors and initiated cultivation practices relating to wild plants. A range of new tools was developed, facilitating innovative methods for food procurement and material manipulation. Storage facilities were constructed to manage food surplus, providing the first evidence for a delayed-return economic system (Woodburn 1982). This changing economic organisation accompanied a transition from relatively egalitarian social systems to those based on more complex relationships. These features continued into the less well-defined EPPNB (c. 8,800-8,600 cal BC) period: a transitional period characterised by a combination of circular PPNA and rectilinear MPPNB architectural forms. EPPNB communities increased resource exploitation and introduced more efficient and effective tool technology, such as naviform core technology: a specialised lithic reduction technique that enabled systematic blade production.

The widespread adoption of a sedentary existence and increasing intensification of resource exploitation during the MPPNB (c. 8,600-7,400 cal BC) significantly altered the way humans interacted with each other and their environment. Settlement forms demonstrate considerable regional variation, with particular distinctions between the northern and southern regions of the Levant and between the Mediterranean and more marginal, arid zones. MPPNB communities exploited a variety of domesticated plants including wheat, barley, flax, peas, lentils and chickpeas and there are signs of incipient pastoralist practices relating to ovicaprines. Secondary production technologies emerged, including milk and wool production and lime plaster production for use as a building material and for ritual items, such as anthropomorphic figurines, painted skulls and limestone masks. Lime plaster and other items, such as beads and pendants, were extensively and systematically manufactured, indicating increasing craft specialisation, potential centralised control of labour and resources, and increasingly complex social organisation. The formalisation of ritual practices may have served as a control mechanism to facilitate community cohesion with these larger and more diversified populations.

Rapid population expansion and aggregation produced large villages during the MPPNB (up to 5 ha). Social crowding and unsustainable resource exploitation may have contributed to the decline and abandonment of many villages between the MPPNB and the LPPNB (c. 7,400-6,700 cal BC). Numerous communities appear to have relocated to more marginal areas to the east and along the littoral zone. Plant and animal domestication increased with fishing and exploitation of marine resources supplementing diets within coastal settlements, resulting in a varied diet that minimised risk from adverse environmental conditions. Ritual practices were enhanced with more distinctive communal or ritual architecture and increased association of animal skeletal elements and grave goods with burials. Very large villages, or "mega-sites" (> 7 ha) emerged, requiring greater labour diversification and more elaborate control mechanisms. The impact of these settlements on the environment must have been considerable and may have contributed to population contraction at the end of the LPPNB and into the PPNC (c. 6,700-6,400 cal BC).

The PPNC (c. 6,700-6,400 cal BC), termed the Final PPNB by some, is characterised by a general decline in population and reduction in the range of domesticated plant and animal species. Whilst, limited effort was devoted to the construction of residential structures, a high degree of effort was devoted to large-scale community structures including rubbish facilities, wells and large walls. This may indicate declining self-sufficiency of individual households and a shifting focus toward whole settlement autonomy and preservation. The PPNC persisted for around 300 years until the introduction of pottery around 6,400 cal BC.

Archaeologists have developed a sophisticated understanding of PPN cultures in the central and southern Levant, including knowledge of settlement structure, organisation and distribution; resource management and exploitation; technology and secondary manufacturing practices; ritual and mortuary practices; and trade and exchange networks. However, more precise demographic data is required to explain how and why populations aggregated and expanded during this period and what influence this had on early village development and the relationship between humans and the environment. This need for demographic data and the underlying methodological and theoretical frameworks for existing early village population estimates are examined in the following chapter.

4 Estimating Early Village Population Parameters

An essential element in reconstructing past cultures is the ability to estimate the size, density and dynamics of a society's population. Although the term 'population' can be fluid, in an archaeological context it refers to the total number of people within a social unit with shared linguistic, cultural or historical traditions, who are normally co-resident or within close geographical proximity (Chamberlain 2006, p.1). In archaeological demography, the population is considered a single entity for quantitative analyses in order to explore differences in population size, density and dynamics that may be linked to socio-economic and socio-cultural factors. Population size refers to the total number of individuals in a population; population density refers to the number of individuals occupying a unit of space or the amount of space occupied by an individual; and population dynamics refers to the growth or decline of population size (Chamberlain 2006, p.2). These estimates enable palaeodemographers to establish trajectories of human social development by framing important questions relating to changing subsistence strategies, technology, community organisation, and socio-political and religious institutions (Hershkovitz and Gopher 2008).

Estimates of demographic parameters are particularly important for developing theories based on cultural evolutionary and structural-functionalist approaches, providing a link between the demographic constitution of a population and evidence for the often increasing diversity and complexity in cultural systems (Steward 1955; Barth 1956; White 1959; Fried 1967; Feinman 2000; Johnson and Earle 2000; Shennan 2001; Henrich 2004; Kline and Boyd 2010; Castro and Toro 2014; Verwiebe 2014; Andersson and Read 2016). For example, estimates of population size in hierarchical and non-hierarchical societies have been used to determine the coevolution of population size and leadership in pre-Hispanic Pueblo communities (Kohler *et al.* 2012); population density estimates have been used to explore the relationship between population density, resource diversification and food niche expansion and contraction (Neeley and Clark 1993); and population growth and decline models have been used to explore 'boom' and 'bust' periods following the introduction of agriculture (Shennan *et al.* 2013).

The estimation of population parameters is, as Renfrew (1972, p.383) states, "one of the most perilous exercises in prehistoric archaeology". Nevertheless, given the importance of demographic data for understanding socio-cultural development, archaeologists continue to explore methodologies for producing increasingly precise estimates. This chapter provides a detailed discussion of four commonly utilised methodologies for estimating population parameters of early and formative villages, highlighting some of the major underlying theoretical and methodological considerations. A summary of existing estimates of population parameters for PPN central and southern Levantine villages is presented, highlighting the major limitations and the need for more empirically and statistically robust methods. A new method devised in this investigation is then presented: the storage provisions formulae (SPF). This is followed by a discussion of the relationship between group size and cultural evolution, with specific reference to hypothesised group size thresholds potentially relevant to the PPN.

4.1 Methodologies for estimating early village populations

The most common methodologies for estimating population parameters of early village societies are based on residential data, including the number and size of dwellings, household size and floor area per person; and settlement data, including settlement size and population density. These methodologies usually employ density values derived from ethnoarchaeological analysis. Modern Southwest Asian villages are commonly utilised as comparative ethnographic examples when investigating PPN settlements despite (1) the sometimes considerable environmental differences between the early Holocene and the modern day, particularly in the more arid regions to the south; and (2) the potential impacts of modern religion and infrastructure on settlement layout and social organisation. Use of this ethnographic data should be combined with (or possibly rejected in favour of) ethnographic case studies in more comparable environmental settings, for example, the historical and contemporary formative villages in Mesoamerica and North America (Hayden *et al.* 1996; Bandy 2006). Archaeological evidence also suggests that these villages may demonstrate more comparable structural features to PPN settlements (i.e. circular pit houses similar to those in the earlier PPN and pueblo-style settlements with agglomerated, rectangular structures similar to those in the later PPN), as well as more comparable subsistence practices (i.e. hunter-gatherer and low-level food production) (Hill 1970; Hayden *et al.* 1996; Diehl 2001; Bandy and Janusek 2005; Bandy 2006).

The following sections outline the four most commonly utilised methods for estimating population parameters: the housing unit method (HUM); the residential area density coefficient (RADC) method; the settlement population density coefficient (SPDC) method; and allometric growth formulae (AGF). For each method, demographic data derived from ethnographic and archaeological research in Southwest Asia and comparable contexts elsewhere is presented. Each of these methods can be applied at the micro-level to estimate the population of individual sites based on site-specific archaeological data; or can be applied systematically to multiple sites based on site extent and average values for constants (i.e. the number of people per dwelling or the number of people per hectare) that may be applicable across broad cultural horizons.

4.1.1 Housing unit method (HUM)

The housing unit method (HUM) calculates population size by multiplying the average number of people residing in a dwelling by the number of dwellings within a settlement. These methods rely on the assumption that the number of residential dwellings directly relates to the number of inhabitants. Nelson (1909) was amongst the first to utilise this method in an archaeological context to estimate the population of a San Francisco Bay shell mound, multiplying the number of house depressions by an arbitrary figure of six people per house. The method was subsequently widely explored, particularly with the rise of processual archaeology in the 1960s.

Archaeologists quickly acknowledged a number of methodological and theoretical issues with this method, the foremost of which was the use of a standard figure for household size and debate regarding the constitution of the 'household'. In modern terms, a household is loosely defined as "a house and its occupants regarded as a unit" (Stevenson and Waite 2001, p.691). Archaeologists generally agree that households represent a social and economic unit, which makes common provisions for living essentials, including food and shelter (Pressat 1985). Household members may reside in a single building, an apartment or within several buildings, and may even have members who reside in dormitories or other communal structures (Wilk and Rathje 1982; Netting 1982; Netting *et al.* 1984; Brown 1987). The term 'household' is often used interchangeably with that of 'family'. However, Kramer (1982) asserts that such conceptually defined terms do not reflect the considerable intra-site and cross-cultural variability in the nature of the household.

Indeed, households constitute a variety of family types, engaged in various marriage practices, following different post-marital residence practices. For example, a study of aboriginal Californian settlements indicated that the majority were occupied by single nuclear family dwelling units (i.e. a couple and their offspring) (Cook and Heizer 1968, pp.89-91), whilst analysis at Tell-i Nun, Iran, indicated that compounds were inhabited by variable dwelling unit types, including single nuclear families (48.2%), single nuclear families with one or two dependent relatives (12.5%) and extended families (37.5%) (i.e. two or more co-resident nuclear families or nuclear families with several dependent relatives) (Jacobs 1979). A cross-cultural analysis of marriage practices by Murdock (1981) revealed that 75% of communities engaged in polygamous marriage. Murdock (1981) also found that patrilocal post-residence marriage practices were more common than matrilocal practices. Different post-marital residence practices have been linked to differential use of space in ethnographic examples (see Section 4.1.2).

For the purpose of population estimates, the term ‘household’ has come to mean the total number of people living within a single dwelling, a notion more accurately reflected by the terms ‘dwelling unit’ (Wilk and Rathje 1982, p.620) or ‘domestic group’ (Hammel and Laslett 1974, p.76). To determine how many people formed this dwelling unit, archaeologists usually employ ethnographic analogy. Southwest Asian ethnographic villages, often used as comparative examples for PPN settlements, usually comprise nuclear family dwelling units averaging around five to six people (Sweet 1960; Wright 1969; Antoun 1972; Watson 1978; 1979; Kramer 1979; 1982; Aurenche 1981; van Beek 1982; Finkelstein 1990; Zorn 1994) (Table 4.1). This equates to units of two adults and three to four children.

It has been suggested that earlier PPN settlements with circular dwellings and shared storage may have been inhabited by polygynous communities, in which each dwelling was occupied by an individual or possibly an adult and their offspring; whilst later PPN rectangular dwellings, which were larger, more compartmentalised and contained private storage, may have accommodated monogamous nuclear or extended family units (Flannery 1972; 2002; Byrd 2002). Within several earlier PPN settlements, such as Dhra’ and WF16, residential structures are not clearly discernible, raising debate regarding co-residence patterns and the use of a standard dwelling unit type (Finlayson *et al.* 2011).

The predominant theory, however, is that nuclear families formed the main dwelling unit type throughout the PPN. This is based on:

- interpretations of internal features, such as the number of hearths per structure (usually one) often equated to the number of families (Heidenreich 1971; Milisauskas 1972; Wright 1974; Starna 1980; Trigger 1981; Dodd 1982; Warrick 1983; Byrd 2002);
- evidence for dwelling-based food storage, processing and consumption activities of a sufficient scale to support single family units (Turner and Lofgren 1966; Bar-Yosef *et al.* 1991; Byrd 1994; 2002; Wright 2000; Rosenberg 2008; Goring-Morris and Belfer-Cohen 2011);
- sub-floor burials and reburial throughout the lifespan of a structure at the majority of PPN sites, including Motza (Khalaily *et al.* 2007), Jericho (Kenyon 1965; 1981) and Wadi Shu’eib (Simmons *et al.* 2001), which have been interpreted as representing long-term generational connections with space (Watkins 1992);

- workshop areas associated with dwellings, as at Beidha (Byrd 2005a), el-Hemmeh (White 2013) and Ba'ja (Kinzel 2013), which provide evidence for the vertical transfer of technological knowledge throughout these generations (Atienzar and Maestre 2011, p.21); and,
- settlement spatial organisation and structural developments, including orientation of entrances away from central areas, the transition to rectilinear architecture and repeated modifications and compartmentalisation, as at Tell Qarassa (Ibañez *et al.* 2010), Ghwair I (Simmons and Najjar 2006) and Basta (Nissen 2006), which may indicate a desire for household privacy and increasing occupant numbers (Rosenberg and Redding 2002; Byrd 2002; Kuijt 2004b; Byrd 2005b, p.232; Asouti 2013).

Based on the theory that nuclear families formed the predominant dwelling unit type and ethnographic data relating to nuclear family sizes, a dwelling unit size of five to six people is often proposed for Neolithic settlements (Sweet 1960; Kramer 1982; Rollefson and Köhler-Rollefson 1989; Düring 2001; Byrd 2002; 2005a).

Some archaeologists have explored alternative methods for deriving dwelling unit size. For example, Turner and Lofgren (1966) based their estimates for prehistoric Western Pueblo Indian longhouses on the capacity of serving bowls, cooking jars and ladles. An average serving size per person of 691 cm^3 was determined from mean bowl capacity and used as a divisor to determine the amount of people served from vessels of various sizes. They deduced an average dwelling unit size of around 4.5 to 5.2 people.

For the phases of Çatalhöyük contemporary with the PPNB, Mellaart (1967) explored two methodologies: the first estimated an average dwelling unit size of four to five people based on the number of burials; and the second estimated an average of three to four people (with a maximum of 8 people) based on the capacity of sleeping compartments. For Pottery Neolithic Çatalhöyük, Düring (2001) examined sleeping platform capacity, estimating that larger platforms (2.6 x 1.3 m) could accommodate up to two adults/adolescents and that smaller platforms (1.3 x 1.3 m) could accommodate two to three children. Düring (2001) proposed an average dwelling unit size of four to five people.

At PPNB/PPNC 'Ain Ghazal, Rollefson and Köhler-Rollefson (1989, p.79) first estimated the total population size using van Beek's (1982, pp.64-65) ethnographically derived density values of 286 to 302 people per hectare at Tell Marib, North Yemen. This estimate was reduced by 20% based on an 80% structural contemporaneity value (i.e. the proportion of structures suggested to be in contemporaneous use) and divided by a total estimated number of dwellings based on van Beek's (1982, p.63) value of 63 buildings per hectare (also identified at Tell Marib) to derive an average dwelling unit size of six people. Van Beek's (1982) original estimates incorporated dwelling units predominantly comprising nuclear families. Thus, Rollefson and Köhler-Rollefson's (1989) estimate could be deemed to roughly equate to two adults and four children.

The HUM can be applied at the micro-level by extrapolating the total number of dwellings within a site from the excavated evidence and multiplying this by an appropriate dwelling unit size (or sizes). The theory that nuclear families occupied PPN settlements is tested in this investigation by applying dwelling unit sizes of three people (the smallest possible nuclear family size) to eight people (a large nuclear family size). Where excavation evidence is lacking, the HUM can be employed systematically, using a regional population density coefficient (RPDC) for the number of dwellings per hectare derived from micro-level analyses of comparable sites. Although usually employed to estimate regional population based on aggregate occupied area (Wendt and Zimmermann 2009; Zimmermann *et al.* 2009), this method could be used to estimate the population of individual sites by multiplying an RPDC by site extent (in hectares) to derive the total number of dwellings per site, and multiplying this by appropriate dwelling unit sizes. An alternative, though more complicated, method for deriving the total number of dwellings per site could involve applying a constant for the proportion of residential built area in site area (RBAP) to site extent to estimate the total residential built area per site, and then dividing this by the mean residential built area of dwellings.

These methods would enable site-specific population estimates to be derived based on limited data (i.e. site extent and constants produced via micro-level analysis). However, the use of constants is problematic, firstly due to the assumption that sites analysed at the micro-level are representative of the cultural horizon under investigation; and secondly, the further removed the constant becomes from the source of the data, the greater the potential for compounding errors. In addition, the application of these methods, both at the micro-level and systematically, requires consideration of several common methodological issues relating to site extent estimates, representativeness of the excavated area, identification of residential area and dwellings, and the degree of structural and site contemporaneity (i.e. the number of structures or sites in contemporaneous use). These issues are discussed in detail in Section 4.2.

Table 4.1. Dwelling unit sizes derived from ethnographic and archaeological analysis.

Site/Region	People/ dwelling	Notes	References
Single site ethnographic analysis			
Tell Togaan, Syria	5.6	Single nuclear families (68%)	Sweet 1960
Sayeh South, Iraq	6		Wright 1969
B'dair, Iraq	5.6		Wright 1969
Daghghara, Iraq	5.6		Wright 1969
Kufr al-Ma, Transjordan	6.5		Antoun 1972
Hasanabad, Iran	4.4		Watson 1978
Hasanabad, Iran	4.59		Watson 1979
Shahabad, Iran	5.1/6.3	Landless/landed households	Kramer 1979
Tell-I Nun, Iran	4.8/8.75	New, unwalled section/old, walled section; single nuclear families (48.2%), extended families (37.5%), nuclear families with 1-2 dependent relatives (12.5%)	Jacobs 1979
Marib, North Yemen	5		van Beek 1982
Aliabad, Iran	6.2		Kramer 1982
Seker al-Aheimar, Syria	8		Portillo *et al.* 2014
Regional and cross-cultural ethnographic analysis			
18 regions: California	6		Cook and Heizer 1968
14 villages: North America, Alaska	5		Cook 1972
29 villages: Near East	5.3/6.4	Site extent < 3 ha/> 3 ha	Aurenche 1981
40 villages: Aliabad region, Iran (not incl. Aliabad)	5.3		Kramer 1982
95 villages: Lake Patzcuaro Basin, Mexico	5.97	1940 and 1970 census data	de Roche 1983
Mesoamerican villages	5.5		Kolb 1985
113 villages: Palestine/Ephraim	4.3-6.1	19th century census data collections	Finkelstein 1990
20 villages: North America, Alaska, Artic Circle	5		Hayden *et al.* 1996
Archaeological analysis			
Western Pueblo Indians, Arizona (AD500-1900)	4.5-5.2	Based on vessel capacity	Turner and Lofgren 1966
Çatalhöyük, Turkey (PPNB)	3-4	Based on sleeping compartments (max = 8)	Mellaart 1967
Çatalhöyük, Turkey (PPNB)	4-5	Based on number of burials	Mellaart 1967
'Ain Ghazal (PPNB-PPNC)	6	Based on estimated population size and estimated number of contemporaneous houses; 2 adults/4 children	Rollefson and Köhler-Rollefson 1989
Çatalhöyük, Turkey (Pottery Neolithic)	4-5	Based on sleeping platforms; 2 adults or adolescents/2-3 children	Düring 2001

4.1.2 Residential area density coefficient method (RADC)

A residential area density coefficient (RADC) is a measure of the amount of residential space per person (Table 4.2). Population size is calculated by dividing the total amount of residential space by an RADC. This method was first explored in an ethnoarchaeological context by Naroll (1962), who attempted to derive a universal constant for the amount of roofed floor area per person by examining data relating to roofed floor area and total settlement population within 18 nomadic and sedentary societies from North and South America, Africa, Oceania and Eurasia. The majority of sites were large, with agglomerated, rectilinear architecture. Naroll (1962) identified an allometric relationship between the two variables ($A = 21.7 \times P^{0.84195}$), where A is the roofed floor area and P is the population size (discussed in detail in Section 4.1.4). The formula was simplified to $P = A/10$, producing an average of 10 m^2 roofed floor area per person. Naroll's (1962) constant was criticised for being too simple and for having the potential to underestimate population by including all roofed floor area as opposed to living and/or sleeping space only (Cook and Heizer 1968; Nordbeck 1971; Wiessner 1974; Schacht 1981; Kolb 1985; Brown 1987; Byrd 2002). Despite this criticism, Naroll's (1962) constant has been widely utilised in archaeological contexts, although most studies emphasise the need to develop constants for different types of settlements, and for different dwelling forms and units (LeBlanc 1971; Flannery 1972; Milisauskas 1972; Marfoe 1980; Kramer 1982; van Beek 1982; Kolb 1985; Finkelstein 1990).

Several variables impact the amount of personal floor area allocation. For example, smaller personal space allocations are usually recorded within more mobile communities (Porčić 2012) and those located within extremely cold conditions (Brown 1987; Hayden *et al.* 1996). Alternatively, larger space allocations have been recorded in communities that follow matrilocal post-marital residence patterns and in settlements of larger populations. This has been interpreted as an attempt to increase privacy, particularly relating to female practices and conditions, and to mitigate the effects of overcrowding (Flannery 1972; Brown 1987). The correlation between wealth and personal space allocation is variable. Kramer (1979) recorded no correlation at Shahabad, Iran, whilst Hayden *et al.* (1996, p.157) recorded a positive correlation in Arctic settlements, where lower occupant density was recorded in dwellings of wealthier families, who could afford to maintain fires.

Archaeologists have argued that RADCs should be based on living area only, omitting non-living area, such as walls, stairs, storage space, kitchens, workshops, courtyards and animal pens (Hill 1970; LeBlanc 1971, p.211; Kramer 1979; Hayden *et al.* 1996). In this way, RADCs apply to potential sleeping area only, which more accurately reflects the resident population. The few analyses that have employed this method produced considerably more constrained constants (2.16-4.82 m^2 living area per person) (Hill 1970; Kramer 1979; Hayden *et al.* 1996). Lower RADCs were derived from settlements with curvilinear structures (Hayden *et al.* 1996), whilst higher RADCs were derived from settlements with rectilinear structures (Hill 1970; Kramer 1979). Unfortunately, due to the difficulties associated with identifying potential sleeping area, investigations generally do not employ this methodology.

There has been little attempt to refine RADCs for PPN settlements. Byrd (2002, p.72) measured the interior area of 106 domestic structures from southern Levantine sites spanning the Early Epipalaeolithic to the PPNB. He applied Naroll's (1962) constant of 10 m^2 roofed floor area per person to the mean interior area measurements to determine whether domestic structures were inhabited by individuals, or nuclear or extended families. Byrd (2002) suggests that Naroll's constant is too high for settlements occurring during this period, although he does not propose a more suitable value.

In this investigation, population estimates are derived from RADCs relating to residential floor area only. The range of RADCs employed is based on the limited number of constants outlined above (c. 2-5 m^2). The RADC method is applied at the micro-level by extrapolating the total residential floor area within a site from the excavated evidence and dividing this by the amount of residential floor area per person. The RADC method could be employed systematically to estimate the total residential floor area per site by applying a constant for the proportion of residential floor area in site area (RFAP) to site extent.

Table 4.2. Residential area density coefficients (RADC) derived from ethnographic and archaeological analysis.

Site/Region	RADC - m^2/person	Notes	References
Single site ethnographic analysis			
Broken K Pueblo, Southwest America	4.55	Dwelling unit size of 6.1 people; based on living area only	Hill 1970
Hasanabad, Iran	7.3		Watson 1978
Shahabad, Iran	4.82	Based on living area only	Kramer 1979
Shahabad, Iran	8	Based on living and kitchen area only	Kramer 1979
Marib, North Yemen	9.9-10.4		Van Beek 1982
Baghestan, Iran	8		Horne 1994
Regional and cross-cultural ethnographic analysis			
18 societies: N and S America, Oceania, Africa, Eurasia	10		Naroll 1962
18 regions: California	1.86	1.86 m^2 for first 6 people; 9.3 m^2 per additional person thereafter	Cook and Heizer 1968
2 Samoan fisher-farmer settlements	13.2/9.8		LeBlanc 1971
2 Peruvian haciendas	12.8/8.2		LeBlanc 1971
Rural villages: Iran	7-10		LeBlanc 1971, Kramer 1982
Villages: California (1), American SW (10)	4.21	21.07 m^2 per nuclear family of 5 people	Cook 1972
New World and Ontario Iroquoian longhouse settlements	6	Multifamily dwellings	Casselberry 1974
Southwest American pueblos	3.33		Clarke 1974
Mesoamerican villages	6.12	Average nuclear family dwelling unit of 5.5 people; based on floor area of kitchen, bedroom/s and storage rooms	Kolb 1985
38 societies: worldwide	6		Brown 1987
Abandoned Palestinian houses	9.65		Finkelstein 1990
20 villages: N America, Alaska, Artic Circle	2.16	Based on living area only	Hayden *et al.* 1996
35 sedentary societies	6.97		Porčić 2012
11 mobile communities	3.25		Porčić 2012
Archaeological analysis			
Keatley Creek, British Columbian pit house village (Prehistoric)	2.8-3.8	Number of hearths = number of families; family size of five people; based on living area only	Hayden *et al.* 1996

4.1.3 <u>Settlement population density coefficient method (SPDC)</u>

A settlement population density coefficient (SPDC) is a measure of the amount of people living within a hectare. The most common method for estimating population size is to multiply total site extent by an ethnographically derived SPDC. SPDCs derived from single-site ethnographic analysis of Southwest Asian villages vary from around 16 to 334 people per hectare (Table 4.3) (Jeremias 1969; Wright 1969; Antoun 1972; Watson 1978; 1979; Jacobs 1979; Kramer 1979; 1980; 1982; Van Beek 1982). Regional ethnographic analyses tend to produce a more limited range, usually between 100 and 200 people per hectare, with higher densities (mostly in the range of 100-600 people/ha) estimated for archaeological sites (Sumner 1979; Shiloh 1980; Adams 1981; Aurenche 1981; Kramer 1982; Zorn 1994; Drennan and Peterson 2008). Wossinik (2009, p.59) plotted densities and settlement size of villages, towns and archaeological sites. Each of these settlement types produces different regression lines (Figure 4.1). For example, there appears to be a weak negative correlation between density and settlement size in modern villages, a weak positive correlation in modern towns and a relatively strong negative correlation in the few archaeological sites assessed.

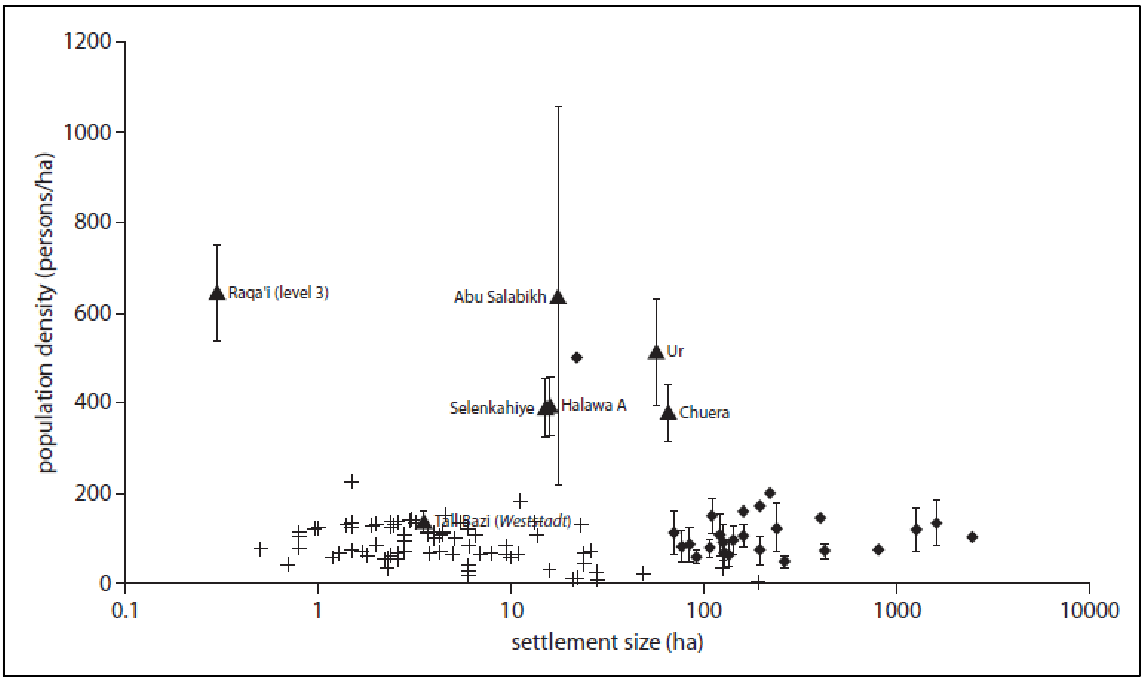


Figure 4.1. Correlation between population density and settlement size (in logarithmic scale). Crosses indicate villages assessed by Aurenche (1981, Table 3) and Kramer (1982, Table 5.3); diamonds indicate towns assessed by Kramer (1982, Table 5.6); and triangles indicate archaeological sites (Wossinik 2009, p.59).

Higher population densities (~300 p/ha) are often recorded for settlements located in economically advantageous areas, such as coastal plains (Finkelstein 1990); and for walled settlements, such as Jerusalem (Jeremias 1969), Tell-i Nun, Iran (Jacobs 1979) and Marib, North Yemen (van Beek 1982). Both positive and negative correlations have been identified between population density and settlement or population size. Sumner (1979) identified that larger villages (P ≥ 400) in the Marv Dasht region exhibited a higher SPDC (155 p/ha) than smaller villages (P < 100) (70 p/ha). Finkelstein (1990, p.50) revealed a similar positive correlation for Palestinian villages, where larger villages (P > 1000) produced higher densities (189 p/ha) due to less abandoned residential space than smaller villages (P < 300; 141 p/ha).

Conversely, in an analysis of Near Eastern villages, Aurenche (1981) recorded the lowest population densities (31 p/ha) in the largest villages (> 10 ha) and the highest population densities (111 p/ha) in smaller villages (1-3 ha). Whitelaw (1991) identified a similar negative correlation in hunter-gatherer populations (Figure 4.2). Higher densities were recorded within settlements occupied by extended family groups, whose social and subsistence strategies were based on kinship roles and cooperative interaction. Lower densities were recorded for settlements with larger populations, where greater spacing between residence units reflects less familiar and less intensive interactions, and subsistence strategies based on reduced economic cooperation (Whitelaw 1991, p.149). Environmental factors affect density due to variable needs for cooperative food-procurement and sharing strategies, and the relationship between this and household spacing. For example, lower densities are recorded in subarctic, arctic and desert regions, where the foraging of plants and hunting of small game requires limited cooperation between households (Whitelaw 1991, p.168). Variations in density have also been association with occupation duration, with lower densities recorded in settlements occupied for extended periods, potentially linked to mechanisms for relieving tension with long-term neighbours (Whitelaw 1991, p.151).

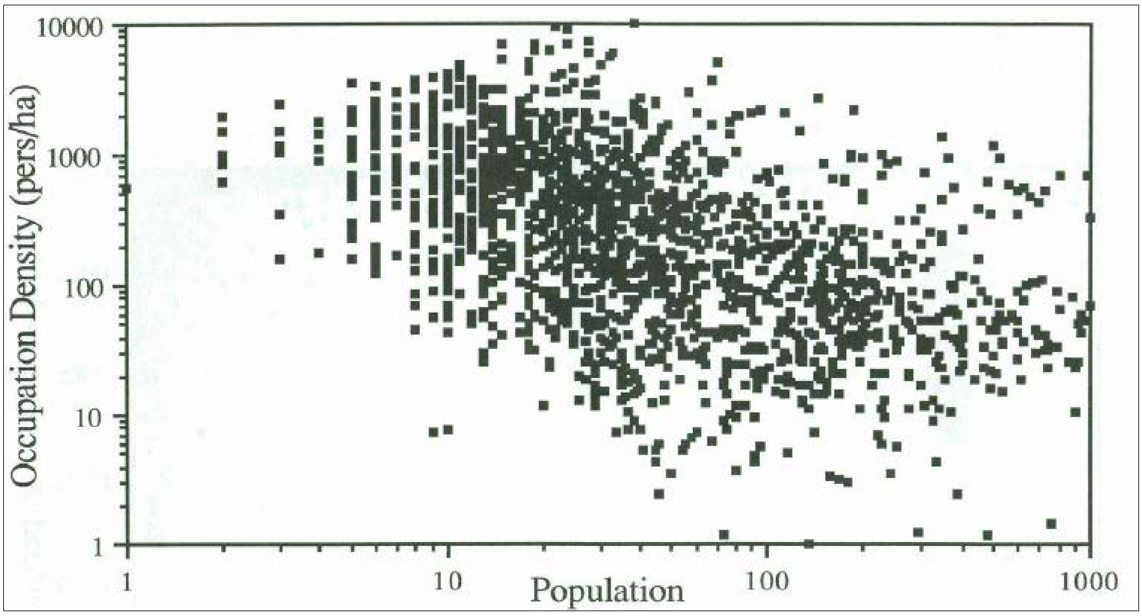


Figure 4.2. Negative correlation between population density and population size in hunter-gatherer settlements (in logarithmic scale) (Whitelaw 1991, p.146).

SPDCs for archaeological sites are usually based on population estimates derived from the HUM and RADC methods. This is problematic as errors resulting from insufficient critique of factors influencing dwelling unit size and the amount of space per person are compounded. Density estimates for archaeological sites vary considerably from around six to 1,250 people per hectare. Higher densities occur within walled settlements (Shiloh 1980; Zorn 1994), highly centralised settlements (Drennan and Peterson 2008) and topographically restricted or compact settlements (Drennan 1988). Density estimates for prehistoric archaeological sites are generally higher than those derived from ethnographic analysis. Sumner (1979, p.172) suggests that this is probably due to a larger amount of built area reserved for domesticated animals in modern settlements when compared to prehistoric settlements.

Several archaeologists have proposed SPDCs for Neolithic settlements. Kramer (1982) advised utilising 100 to 200 people per hectare based on cross-cultural ethnographic analyses. Chapman (1981, p.48) identified that "population densities higher than 100 per hectare are rare for the Neolithic period" and proposed application of 50 to 100 people per hectare to estimate Neolithic Vinca Culture sites in the Central Balkans. Kouchoukos (1998) recommended a similar density coefficient of 100 people per hectare for Neolithic and Chalcolithic (6^{th}-4^{th} millennium BC) villages in Deh Luran and Susiana, Iran. The majority of PPN village population estimates utilise SPDCs derived from ethnographic research of Southwest Asian villages. These generally apply a minimum value of around 90 people per hectare based on research by Jacobs (1979), Watson (1979) and Kramer (1982); an average value of around 140 to 150 people per hectare based on Kramer's (1979; 1982) research and the range generally derived from cross-cultural analyses (c. 100-200 people/ha); and a maximum value of 286 to 302 people per hectare (mean: 294 people/ha) based on van Beek's (1982) research (Rollefson and Köhler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009). Although many researchers utilise this maximum value, Kuijt (2008a, p.290) warns that "in the absence of any clear consensus, it is probably best to employ Kramer's (1982) and Watson's (1979) more conservative, lower estimates for developing population estimates", whilst Fletcher (1981; 1995) warns against the use of any SPDCs for estimating population size due to the wide range in density estimates for small-scale agricultural settlements (c. 50-1,000 people/ha).

In this investigation, the commonly utilised density values (90, 150 and 294 people/ha) are applied at the micro-level. These density values and the resulting population estimates are compared to those derived from other methods (i.e. the HUM and RADC) to explore whether these density values are indeed suitable for PPN settlements. Refined density values may be established for systematic application.

Table 4.3. Settlement population density coefficients (SPDC: people per hectare) derived from ethnographic and archaeological analysis.

Site/Region	SPDC (people/ha)	Notes	References
Single site ethnographic analysis			
Jerusalem City (1920s)	334	Walled village	Jeremias 1969
3 villages: Iraq	16/66/129	Sayeh South/B’dair/Daghghara	Wright 1969
Kufr al-Ma village, Jordan	181		Antoun 1972
Hasanabad village, Iran	132.3		Watson 1978; 1979
Tell-I Nun village, Iran	53.3/85.9	New, unwalled section/old, walled section	Jacobs 1979
Shahabad village, Iran	139/119	1979/1980	Kramer 1979; 1980
Aliabad village, Iran	139		Kramer 1982
Marib town, North Yemen	286-302	Walled village	Van Beek 1982
Regional ethnographic analysis			
110 villages in Marv Dasht region, SW Iran	155/70	Large villages/small villages	Sumner 1979
Villages, Iran	83		Watson 1979
Urban settlements in South Central Iraq	125		Adams 1981
39 Near Eastern villages	31/74/111/74	> 10 ha/3-10 ha/1-3 ha/< 1 ha	Aurenche 1981
40 villages, Aliabad region, Iran	97		Kramer 1982
113 Palestinian villages	189/141	Large (>1000 people)/small (<300 people)	Finkelstein 1990
	99/212/170	Desert fringe/harsh topography/hill country	
Archaeological analysis			
Tall-i Bakun, Iran (4th mill BC)	200-600	Based on 3.6-5.5 people/house & 6-9 m^2 roofed floor area/person	Sumner 1979
Walled urban settlements in Palestine (Iron Age)	400-500	Based on 8 people/house	Shiloh 1980
Villages: Nea Nikomedia/Otzaki, Greece; Knossos, Crete (Neolithic)	100-300	Based on 10 m^2 roofed floor area/person	Halstead 1981
Mesoamerican villages (2000 BC-AD 1519)	50-130/6-12	Compact/dispersed; based on 5.6 people/house	Drennan 1988
Tell Bouqras, East Syria (PPNB)	309	Based on 5 people/house	Boerma 1989-90
Arad City, Israel (c. 3000 BC)	200-250	Based on 10 m^2 roofed floor area/person	Finkelstein 1990
Kfar 'Atia, deserted Palestinian village	190	Based on 4.5 people/house	Finkelstein 1990
Urban settlement at Abu Salabikh, Iraq (3rd mill BC)	248-1205	Based on 4-7 m^2 roofer floor area/person	Postgate 1994
Enclosed urban settlement, Tell en-Nasbeh, Palestine (Iron Age)	200-250/450	Stratum 2/3; based on 4-5 people/house	Zorn 1994
Lower Xiajiadian period (2nd-3rd mill BC.) sites, NE China	306-510/180-420	Small sites/large sites	Shelach 2002
Highly centralised settlements, Chifeng, China (2nd-3rd mill BC)	300-600		Drennan and Peterson 2008
Ugarit, Canaan (1550-1150BC)	550	Based on 6.1 people/house	Kennedy 2013

4.1.4 <u>Allometric growth formulae (AGF)</u>

The majority of investigations highlight a strong positive correlation between population size and settlement size, indicating the potential for settlement size to be used as a proxy for population size and for the creation of formulae to depict this relationship (Cook and Treganza 1950; Naroll 1962; Nordbeck 1971; Wiessner 1974; Sumner 1979; Aurenche 1981; Schacht 1981; Kramer 1982; Hemsley 2008; Wossinik 2009) (Figure 4.3).

The allometric growth formulae (AGF) have potential for accurately estimating population size from area measurements. AGF were first explored in biology to investigate differential growth and biological scaling based on the notion that population size alters relative to settlement area (Huxley 1932). The AGF is expressed as:

$$Y = aX^b$$

where Y is area, X is population size, *a* refers to the initial growth index based on the intercept of the regression line with X, and *b* refers to the allometric coefficient, also known as the scaling exponent, which determines the slope of the regression line. A scaling exponent of one ($b = 1$) signifies isometric growth, where changes in settlement area directly correlate to changes in population size, whilst scaling exponents of less than or greater than one signify allometric growth, where the relationship between area and population size is variable.

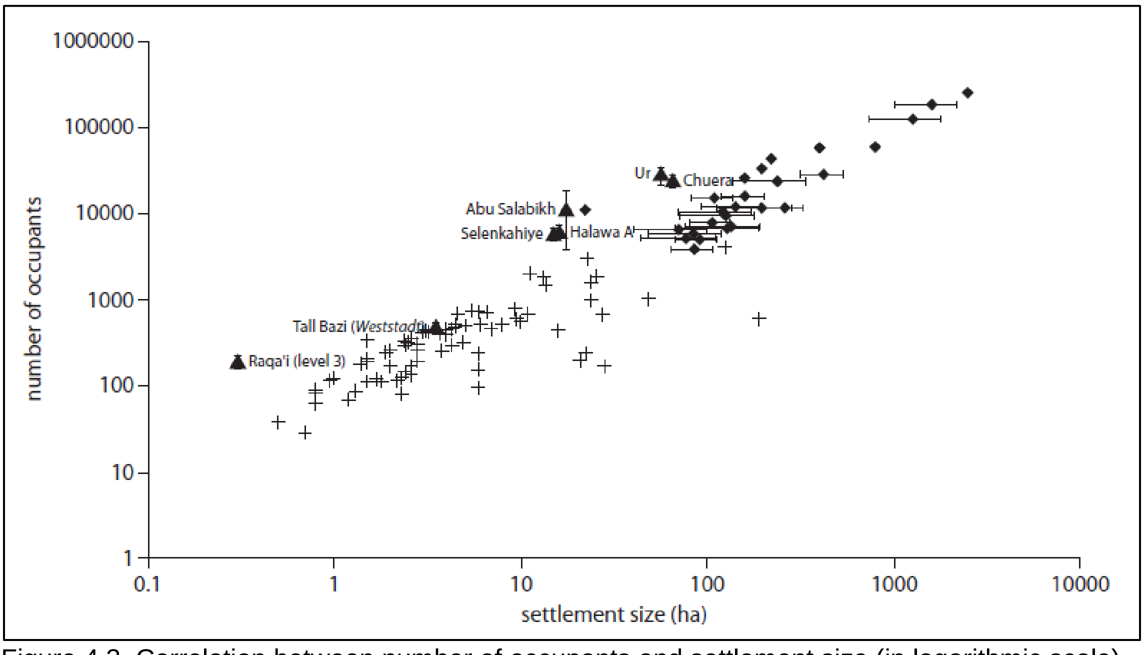


Figure 4.3. Correlation between number of occupants and settlement size (in logarithmic scale). Crosses indicate villages assessed by Aurenche (1981, Table 3) and Kramer (1982, Table 5.3); diamonds indicate towns assessed by Kramer (1982, Table 5.6); and triangles indicate archaeological sites (Wossinik 2009, p.59).

Naroll (1962) was amongst the first to use AGF to investigate human demography. He identified an allometric relationship between built/roofed floor area and population size in ethnographic contexts, noting that the resulting AGF could be beneficial for estimating population size from estimates of roofed floor area particularly within settlements undergoing (or which had achieved) urbanisation. Naroll identified the allometric relationship as:

$$A = 21.7 \times P^{0.84195}$$

where A is the total roofed/built floor area, P is population size, the initial growth index (*a*) is 21.7 and the scaling exponent (*b*) is 0.84195. Naroll converted this to A = 10 m^2. This constant, which directly correlates population to area, was highly criticised as it does not reflect the relationship indicated by the scaling exponent, which reveals a slightly lower rate of increase in roofed/built floor area compared to population size (Nordbeck 1971; LeBlanc 1971; Wiessner 1974).

In 1987, Brown re-examined Naroll's formula, revealing that there was actually no linear or allometric relationship between population size and roofed floor area at the lower end of the scale and only a moderately strong linear correlation at the upper end. As a result, Brown (1987) rejected the use of AGF to explain patterns in settlement and population growth, instead preferring the RADC method. Indeed, Brown and other critics emphasised that considerable cross-cultural and inter-regional variation in the patterns of settlement growth would prevent the application of a single constant for converting settlement area to population size. This acknowledgement led to the refinement of the AGF for different settlement types.

Within urban settlements, Nordbeck (1971) discovered that the settlement profile always contains lower density at the edge or peripheral areas, high density near the centre, and low density at the centre where residences are not often situated. After plotting the site extent and population of around 1,800 modern Swedish urban settlements, Nordbeck identified an allometric relationship represented by the formula:

$$A = 1.30 \times P^{0.664}$$

where A is the total site extent, P is population size, the initial growth index (*a*) is 1.3 and the scaling exponent (*b*) is 0.664. The scaling exponent indicated that settlement area increased at around two-thirds of the rate of the population size increase, due to increased density in suburban areas within urban settlements.

Wiessner (1974, p.349) adopted this scaling exponent for her analysis of urban communities and considered other scaling exponents for open and village settlements. The scaling exponent is based on the dimensional development of different settlement types. For example, open settlements are considered to have a scaling exponent of two (b = 2) as settlement area is deemed to increase by the square of the population size increase. This is based on the notion that open settlements tend to conform to a circumferential pattern, so that when the number of dwellings (or population) doubles, the diameter of the village doubles, resulting in a quadrupling of the settlement size and a reduction in population density (Wiessner 1974) (Figure 4.4, A). This theory was supported by an extensive study of Australian Aboriginal hunter-gatherer, open settlements, which indicated that maximum residential density decreased as community size increased (Fletcher 1990).

For village settlements, the scaling exponent is considered to equal one (b = 1), as it is expected that village settlement area will increase in direct proportion to population size, resulting in constant population density (Chamberlain 2006, pp.127-128) (Figure 4.4, B). This is due to the nature of village expansion, whereby generally single story dwellings and structures are constructed at relatively equal distances from each other.

For urban settlements, the scaling exponent is considered to be two-thirds (b =2/3). This is based on the relationship between area, which is two dimensional, and population, which is three dimensional in urban settings, as these usually contain multi-storey residential structures in the suburban areas. This exponent reflects the smaller relative variation in settlement area when compared to variations in population size and density (Wiessner 1974, p.347) (Figure 4.4, C).

Despite establishing these scaling exponents, the application of this method for estimating population size in archaeological contexts remains largely unexplored. In terms of application to PPN central and southern Levantine settlements, Wiessner's (1974) allometric growth formula for open settlements may be suitable for estimating the population of circular hut compounds, whose inhabitants predominantly relied on hunter-gatherer subsistence strategies, such as Nahal Oren (Noy *et al.* 1973) and Gilgal I (Bar-Yosef *et al.* 2010a; 2010b). The formula for urban settlements may be applicable to those with agglomerated and multi-storey structures, such as LPPNB el-Hemmeh (White 2013), Beidha Phase C (Byrd 2005a) and Ba'ja (Gebel and Hermansen 1999). The formula for village settlements should, theoretically, be applicable to all settlements assessed in this investigation.

In this investigation, the AGF are employed to estimate population at the micro-level using estimates for total built floor area (Naroll's 1962 AGF) and total site extent (Wiessner's 1974 AGF) as the A variable and the related scaling exponents. For Naroll's (1962) AGF, the formula is directly applied to produce population estimates at the micro-level. As Wiessner (1974) does not propose initial growth indices, this AGF cannot be directly applied to calculate population size. It is expected that new initial growth indices will be developed for both AGF from the refined population estimates produced in this investigation, and that these could be applied within the formulae to systematically estimate population size.

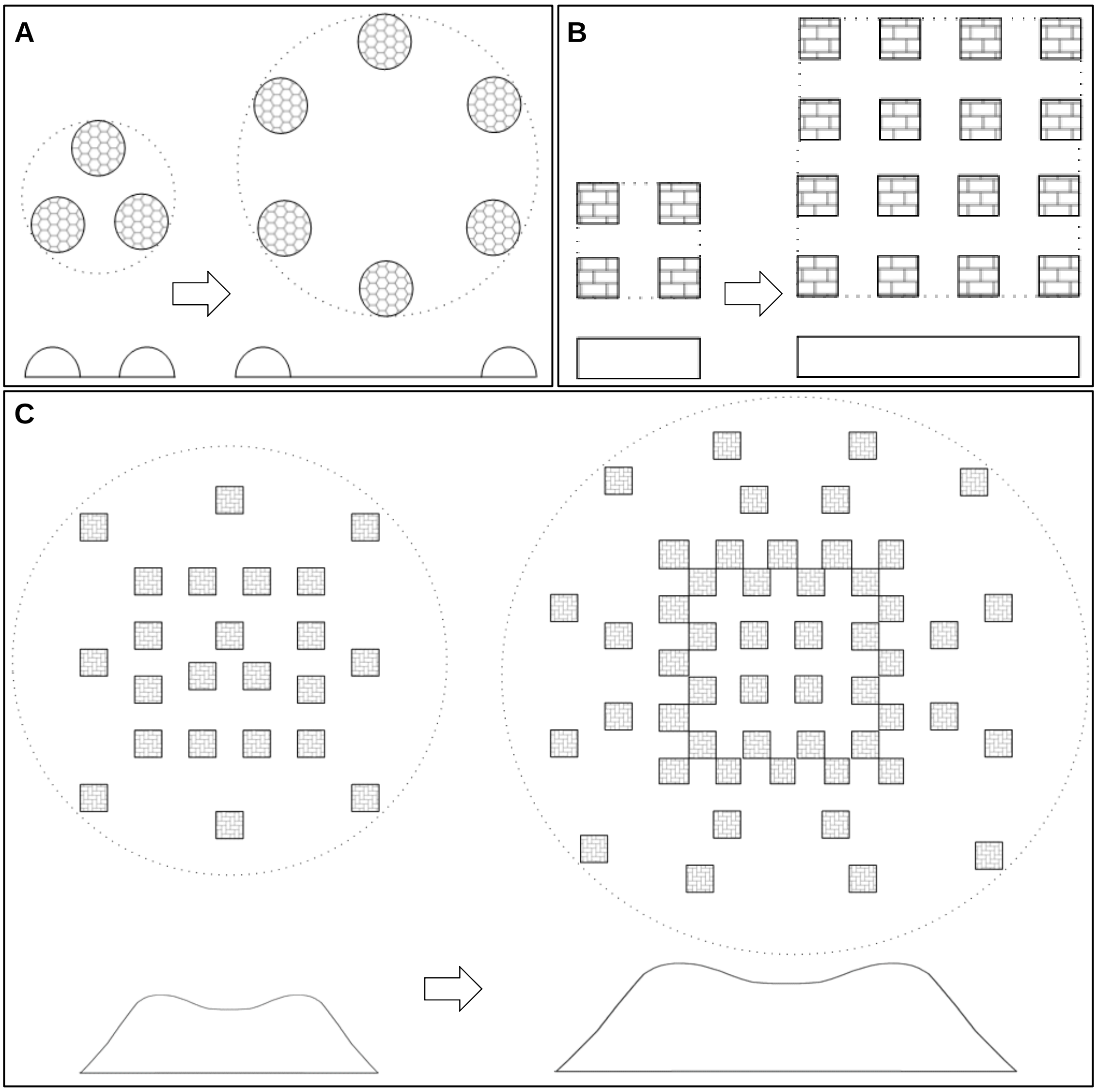


Figure 4.4. Allometric relationship between settlement area (dashed lines), population size (shaded units) and population density (scales underneath) when growth occurs in (A) open, (B) village (isometric growth) and (C) urban settlements (adapted from Wiessner 1974, p.347).

4.2 Major methodological considerations

This section briefly outlines some of the major underlying methodological considerations, including estimates of site extent; the representativeness of the excavated area, particularly relating to structural density; the identification of residential area, dwellings and potential sleeping area; and the degree of structural and site contemporaneity.

4.2.1 Site extent estimates

The determination of site extent is notoriously difficult (Goring-Morris and Belfer-Cohen 2008). Sites are rarely excavated in full and there are numerous factors that affect site preservation. Where estimated site extents are provided in excavation reports, they are most commonly based on delimitation of surface archaeological material, which may have been considerably enlarged (or even reduced) by post-depositional processes. In addition, these estimates usually do not account for "splash zones", which contain displaced and peripheral artefacts (Bandy and Janusek 2005). In many cases it is unclear whether the site extent refers to the surface scatter or the habitable area, and whether this area includes land designated for agricultural or pastoral activities. Most surveys estimate the maximum site extent, which may include multiple periods of occupation (Wossinik 2009). In many cases, the maximum site extent is quoted and applied to all periods. Many PPN central and southern Levantine villages are occupied in several PPN and PN periods. PN occupation phases usually cover the most extensive area, obscuring the extent of earlier occupations.

In the absence of definitive site extent estimates per occupation phase, PPN settlements are often placed within broad site size categories (Aurenche 1981, p.93) or assigned an average period-based site extent founded on the assumption that site sizes remained relatively consistent within each period (Kuijt 2008a, pp.292-294) (Table 4.4). Standardised site sizes and categorisations are beneficial for rapid and comparative assessments. However, to produce absolute population estimates, significant attempts should be made to determine the potential habitable area by identifying possible disused or abandoned areas, open and communal areas, and space designated for agricultural or pastoral activities.

Table 4.4. Categorised and period-based PPN Levantine site sizes.

Aurenche 1981, p.93		**Kuijt 2008a, pp.292-294**	
Site size category	*Site size (ha)*	*Period*	*Average site size (ha)*
Small sites	<1	PPNA	1 (≤ 2.5)
Medium sites	1-3	EPPNB	N/A
Large sites	3-10	MPPNB	2.5 (≤ 5)
Mega sites	>10	LPPNB	10 (≤ 14)
		PPNC	5

4.2.2 <u>Representativeness and structural density</u>

Excavations usually uncover a small proportion of a site from which conclusions are made about the entire settlement. This process relies on the assumption that the excavated area is representative of the total site (Shiloh 1980; Broshi and Gophna 1984; Peterson and Shelach 2012). An essential element for reconstructing population parameters based on the commonly utilised methods is the accurate quantification of built area. Excavation often centres on areas of dense archaeological material, usually architectural remains, distorting perceptions of the degree of built area within a site. For central and southern Levantine PPN settlements, Kuijt (2008a, p.294) estimated period-based ratios of built to open space (Figure 4.5; Table 4.5). In the absence of excavated evidence, these ratios could be beneficial for calculating the total built area from estimates of total site extent.

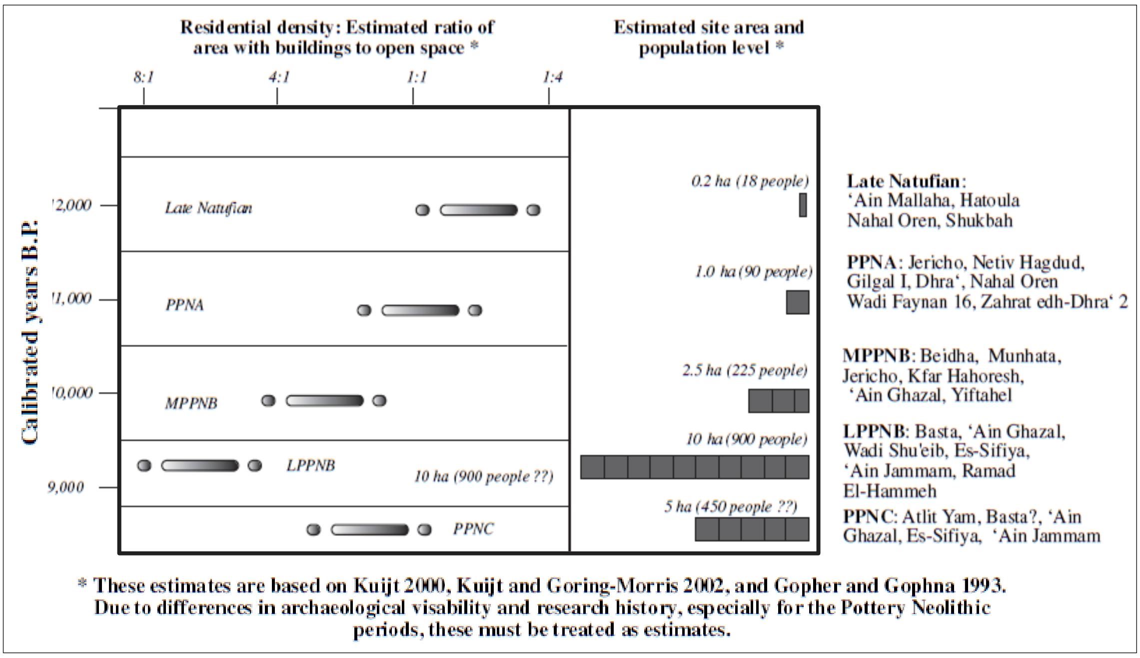


Figure 4.5. Late Natufian to PPNC central and southern Levantine estimates of the ratio between built and open space; and estimated site area and population level. Population estimates are based on ethnographic data from Kramer (1982, p.162) and Watson (1979, pp.35-47) (after Kuijt 2008a, p.294).

Table 4.5. Minimum and maximum PPN period-based proportions of built area in site extent derived from the ratio of built to open area (based on values proposed by Kuijt 2008a, p.294).

Period	**Ratio of built to open area**		**Built area in site extent (%)**	
	Minimum	*Maximum*	*Minimum*	*Maximum*
PPNA	1:2	2:1	33.3	66.7
EPPNB	N/A			
MPPNB	1.5:1	4:1	60	80
LPPNB	4:1	8:1	80	88
PPNC	1:1	3:1	50	75

4.2.3 Identification of residential area, dwellings and potential sleeping area

The majority of methodologies for estimating population parameters rely on identification of residential structures or 'dwellings'. Most PPN structures are interpreted as residential. However, debate exists regarding the accuracy of these interpretations, particularly in the earliest PPN periods where there is limited ability to distinguish between residential and non-residential structures (Finlayson *et al.* 2011). Where 'dwellings' are identified, this is usually based on combinations of features, including hearths, plaster or clay flooring, and sleeping platforms; in-situ artefacts relating to food storage, processing, preparation and consumption; the potential function of associated architectural features (i.e. annexes for cooking and storage); and architectural elements common to residential structures relating to size, morphology (i.e. circular huts and rectangular buildings, partitions/subdivisions, multi-storeys) and construction material (i.e. mud bricks, stone slab foundations, organic and stone superstructures) (Watson 1978; Kramer 1982; Watkins 1990; Byrd 2002; 2005a).

4.2.4 Structural contemporaneity and Bayesian chronological modelling

Although structures within a settlement may appear to have been utilised contemporaneously according to archaeological phases, it is possible that occupation was separated by tens to hundreds of years and that the human processes associated with the archaeological materials were entirely unconnected (Kuijt 2008a). When reconstructing population size, archaeologists must adjust estimates to reflect structural contemporaneity (i.e. the number of structures in simultaneous use). This can be achieved by applying a standard value for the proportion of building contemporaneity (e.g. Rollefson and Köhler-Rollefson (1989) proposed 80% contemporaneity for the PPNB/PPNC village of 'Ain Ghazal) or by deriving formulae for estimating contemporaneity based on archaeological evidence (Schiffer 1987; Varien and Potter 1997; Ortman *et al.* 2007; Varien *et al.* 2007). Varien *et al.* (2007) used the following formula to calculate structural contemporaneity from building use life and occupation span (or phase length):

$$\text{Total number of contemporaneous dwellings} = \frac{\text{building use-life}}{\text{phase length}} \times \text{total number of dwellings}$$

This method relies on the accurate identification of dwellings (previously addressed), and accurate estimates for building use-life and phase length. Archaeological, ethnographic and experimental research of building use-life indicates that earthen and light organic structures, comparable to those which existed in the early PPN, can be utilised for up to 15 years without maintenance and up to 50 years with maintenance (Table 4.6). Conversely, analysis indicates that predominantly masonry structures, comparable to those which existed in later PPN periods, could be utilised for up to 100 years with maintenance.

Table 4.6. Building use-life estimates.

Predominant construction material	**Additional information**	**Building use-life (years)**	**References**
Earthen/light organic	Without maintenance	6-15	Cameron 1990; Reynolds 1995; Diehl 2001; Ortman *et al.* 2007; Arnoldussen 2008; Varien 2012
	With maintenance	15-45	
	PPNA granaries	< 50	Kuijt and Finlayson 2009
Masonry *(all maintained*)	Neolithic Çatalhöyük	50-100	Hodder and Cessford 2004; Cessford 2005; Matthews 2005
	PPNB-PPNC ‘Ain Ghazal	≤ 100	Rollefson and Köhler-Rollefson 1989
	Ancient Southwest America	60	Ahlstrom 1985

A statistically robust method for producing more precise chronological information relating to building use-life and phase length is Bayesian chronological modelling of radiocarbon dates (Buck *et al.* 1996; Bayliss 2007; Bayliss *et al.* 2011). A detailed analysis of the use of Bayesian chronological modelling in an archaeological context was recently conducted by Bayliss *et al.* (2011), who incorporated almost 2,000 radiocarbon determinations into models to refine the chronology of causewayed enclosures during the Early Neolithic of southern Britain and Ireland. The process is outlined in detail with a view to enabling routine employment of Bayesian chronological models by archaeologists.

The Bayesian approach is based on Baye’s theorem (Bayes 1763), which defines probability based on prior knowledge. Bayesian chronological models produce revised probability distributions (‘posterior density estimates’) based on calibrated radiocarbon dates (‘standardised likelihoods’) and prior chronological information derived from archaeological, ethnographic or experimental interpretation (‘prior beliefs’). Effectively, the radiocarbon dates are interpreted in relation to the archaeological and stratigraphic information to produce more precise boundary dates (i.e. start, transition and end dates) and span estimates for specific events and periods (Bronk Ramsey 2009; Bayliss *et al.* 2011).

Bayesian chronological analysis is usually conducted on large radiocarbon datasets to explore large scale population dynamics, often relating to major climatic events or cultural episodes, including human dispersals, the emergence and spread of agriculture, and typological or technological changes (Whittle *et al.* 2011; Riede and Edinborough 2012; Baggaley *et al.* 2012; Benz *et al.* 2012; Higham *et al.* 2012; Talamo *et al.* 2012; Banks *et al.* 2013; Crema *et al.* 2014; Wicks and Mithen 2014; Whitehouse *et al.* 2014; McLaughlin *et al.* 2016; Porčić and Nikolić 2016). Depending on the availability and precision of the prior information, and the number and stratigraphic distribution of radiocarbon dates, it is also possible to model short-term events such as phase length and building use-life. For example, Robb and Marino (2010) estimated spans of events at the Neolithic settlement at Capo Alfiere, Italy, based on just five accelerator mass spectrometry (AMS) dates, using each as constraints for previous and successive events. Marciniak *et al.* (2015) modelled boundary dates and spans for domestic structures and burial chambers at Late Neolithic Çatalhöyük based on 56 radiocarbon determinations. Kerns (2016) refined the chronological sequence of Neolithic chambered cairns and settlements in the Orkney Islands based on over 100 dates from eight sites. In addition, Richards *et al.* (2016) modelled boundary dates and spans for structures at the Late Neolithic settlement of Barnhouse in Orkney based on 70 dates.

Due to the limited number of radiocarbon dates for individual PPN sites and the paucity of information regarding context, sample material and pre-treatment, Bayesian chronological analyses of PPN settlements is rarely conducted. One exception is the recent analysis of 46 AMS dates from the PPNA site of WF16 in southern Jordan (Wicks *et al.* 2016). Chronological models were constructed in the OxCal software (v.4.2; Bronk Ramsey 2009) to produce lower and upper boundary posterior density estimates for the entire site and individual structures (referred to as 'objects' based on the terminology of the database used at the site). As part of this investigation, a methodology was explored to account for the effect of old wood on radiocarbon determinations, producing an offset of 825 to 1,370 years. The site chronological model indicated start and end dates of c. 11,840 to 10,240 cal BP and a span of around 1,590 years, with a summed calibrated probability distribution indicating a period of intense activity lasting for around 350 years centred on c. 11,250 cal BP. Unfortunately, the chronological resolution of models for individual structures was not well constrained due to the limited number of AMS dates per structure, old wood effects, plateaus in the calibration curve and stratigraphic inversion of dates probably resulting from post-depositional processes.

Despite the difficulties associated with Bayesian chronological modelling of PPN phase length and building use-life, the method warrants further investigation. The database of radiocarbon determinations compiled by Benz (2013) provides a sound platform for this analysis.

4.2.5 <u>Site contemporaneity</u>

When attempting to establish regional population estimates, site contemporaneity adjustments should be applied to avoid overestimating population. However, due to the difficulties associated with establishing site contemporaneity, most investigations assume that sites dated to the same chronological phase are contemporaneously inhabited. However, this does not accurately reflect episodes of establishment and abandonment that were taking place over shorter periods. Few analyses have attempted to devise methods for estimating site contemporaneity (Schacht 1984; Sumner 1990) and fewer still propose a contemporaneity value (though Halstead (1981) proposed a contemporaneity value of 10-30% for Neolithic and Bronze Age settlements in Greece). Unfortunately, no suitable method has been identified for determining the proportion of contemporaneously occupied sites during the PPN of the central and southern Levant. Until a method is discovered, the estimates produced in this investigation cannot be considered to represent the total regional population.

4.3 Existing estimates for PPN central and southern Levantine villages

There have been limited attempts to estimate absolute population parameters of PPN villages. The few published instances of absolute estimates of population size, density and growth are summarised below.

4.3.1 <u>Population size</u>

An extensive literature review revealed absolute population size estimates for 23 PPN central and southern Levantine villages (Figure 4.6). These include around 60 estimates derived from seven investigations (Kramer 1982; Rollefson and Köhler-Rollefson 1989; Gebel and Hermansen 1999; Kuijt 2000; 2008a; Ladah 2006; Campbell 2009). All but one (Gebel and Hermansen 1999) employed the same method involving the application of a population density coefficient derived from Southwest Asian ethnographic research, and all use van Beek's (1982, pp.64-65) density coefficients of 286 to 302 people per hectare to produce maximum estimates.

The majority of estimates (*n* = 42) were produced by Kuijt (2000, p.81; 2008a, p.294) to explore the relationship between population dynamics and sedentism, food production, food storage, social crowding, social inequality and the collapse of large villages at the end of the PPN. Kuijt's estimates are based on site area (either estimated directly or based on the mean settlement size of the largest sites per period) and mean population density coefficients of 90 and 294 people per hectare derived from ethnographic research in Iran (Watson 1979, pp.35-47; Kramer 1982, p.162) and North Yemen (van

Beek 1982, pp.64-65). Kuijt (2000, pp.82-85) acknowledges that this method requires a series of assumptions relating to the applicability of ethnographic constants to PPN sites, stating that the resulting estimates are more suitable for comparative analysis than as definitive population estimates.

Campbell (2009) produced additional estimates (*n* = 10) for ‘Ain Ghazal, Basta and Jericho to investigate the impact of agricultural practices on the environment. Campbell (2009, p.137) established low, mid-range and high population estimates based on estimated total site extent and ethnographically derived density coefficients of 85.9 (Jacobs 1979, p.178), 139 (Kramer 1979, p.144) and 294 people per hectare (van Beek 1982, pp.64-65). Maximum estimates were utilised to explore worst-case scenarios relating to resource exploitation pressure.

Rollefson and Köhler-Rollefson (1989, p.75) produced estimates for ‘Ain Ghazal (*n* = 6) to explore reasons for settlement collapse at the end of the PPNB, based on total site extent and van Beek’s (1982, pp.64-65) population density coefficient range (286-302 people/ha).

To investigate the relationship between group size and socio-political complexity at Ghwair I, Ladah (2006, p.150) estimated population based on total site extent and a density coefficient of 286 people per hectare (van Beek 1982, pp.64-65).

Bar-Yosef (1986, p.157) re-evaluated estimates of Jericho, suggesting a population of 400 to 900 people based on ethnographic research by Kramer (1982), with no further explanation of the methodology utilised.

Gebel and Hermansen (1999, p.19) employed an alternative method to estimate the population of LPPNB Ba’ja as part of a report on the architectural findings. It was hypothesised that extended families of around eight to ten people formed the predominant dwelling unit and that 50 to 60 families occupied around 0.6 to 0.7 hectares of densely built houses. A final population estimate of 400 to 500 people was proposed. Unfortunately, the authors provide no further information as to how these figures were derived.

An assessment of existing estimates indicates that PPN villages may have been occupied by a maximum of around 500 people during the PPNA; up to 1,400 people by the MPPNB; and up to 4,000 people by the LPPNB. However, the limited methodological basis for these estimates, the considerable estimate ranges and the focus on relative rather than absolute estimates reduce the reliability of these estimates and the efficacy of any subsequent analysis of the relationship between population parameters and other demographic or developmental factors.

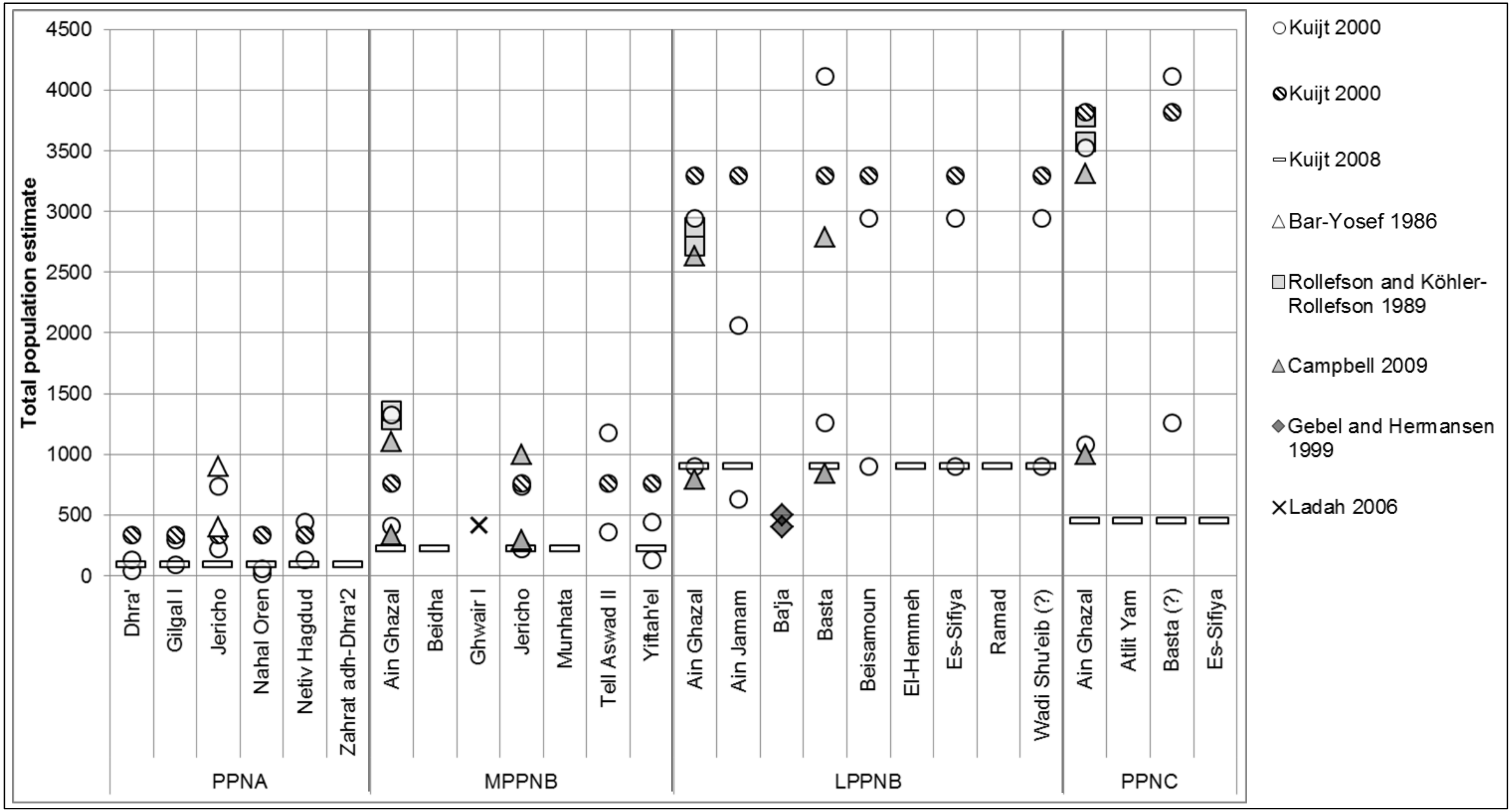


Figure 4.6. Population estimates for PPN central and southern Levantine villages.

4.3.2 Population density

Three types of density are explored in this research: people per hectare; space per person; and people per dwelling.

People per hectare

Ethnographic analysis of Southwest Asian villages and towns has revealed that the majority have a population density range of around 100 to 200 people per hectare, regardless of settlement size or intra-site organisation (Antoun 1972; Aurenche 1981; Kramer 1979; 1982; Wossinik 2009). As previously identified, the primary methodology for producing estimates to date has been via the application of a density coefficient to total site extent. A minimum to maximum range of 90 to 294 people per hectare based on ethnographic research is commonly utilised. Kuijt (2008a, p.290) highlights the wide range in density values, recommending the use of lower values. Density coefficients derived from archaeological analysis of prehistoric and early historic settlements usually range from around 200 to 600 people per hectare (Sumner 1979; Shiloh 1980; Halstead 1981; Finkelstein 1990; Postgate 1994; Zorn 1994; Shelach 2002; Drennan and Peterson 2008; Kennedy 2013). There has been no significant attempt to refine these density coefficients for PPN central and southern Levantine villages. The few density estimates derived for Neolithic settlements include estimates of 100 to 300 people per hectare in Greece and Crete (Halstead 1981) and 309 people per hectare for the PPNB village at Tell Bouqras, East Syria (Boerma 1989-1990).

Space per person

Ethnographic research of Southwest Asian villages and comparable villages elsewhere has produced a wide range of personal space estimates from around 1.86 m^2 to 13.2 m^2 per person (Naroll 1962; Cook and Heizer 1968; Hill 1970; LeBlanc 1971; Clarke 1974; Watson 1978; Kramer 1979; 1982; van Beek 1982; Kolb 1985; Brown 1987; Finkelstein 1990; Horne 1994; Hayden *et al.* 1996; Porčić 2012). This variation is partly due to contextual differences relating to climate, architecture, dwelling unit type and perceptions relating to crowding, privacy and personal space. However, the most significant cause is the inconsistency in the definition of ‘space’. ‘Space’ usually refers to total roofed floor area, although it can refer to total site area, total built area and total residential floor area (that is, the area in which people lived and slept).

When based on residential floor area only, the density coefficient range is considerably reduced to around two to five m^2 per person (Hill 1970, p.75; Clarke 1974, p.286; Hayden *et al.* 1996, pp.152 and 159). Hemsley’s (2008) research into the affordance of space within structures utilises a maximum sleeping area of 1.77 m^2 per person. It would be reasonable to suggest that residential floor area allocations within PPN central and southern Levantine villages lie somewhere between 1.77 m^2 and five m^2 per person. Residential floor area density coefficients have the potential to produce accurate population estimates, provided that residential floor area can be identified in the archaeological record. However, due to the methodological issues associated with identifying this area, archaeologists do not generally propose precise personal space allocations and have generally avoided this technique for estimating PPN village populations.

People per dwelling

There is considerable debate regarding PPN dwelling unit size. Estimates of the number of inhabitants per dwelling require consideration of two main aspects: the first relates to the composition of the dwelling unit (i.e. an individual, a couple or pair, a nuclear or extended family, or a non-related group); whilst the second relates to the number of people typically thought to comprise that particular dwelling unit. For PPN central and southern Levantine villages, a dwelling unit size of five to six people is commonly utilised based on the theory that dwelling units predominantly comprised nuclear families and ethnographic research of nuclear family sizes in Southwest Asian villages. Byrd (2002, p.90) suggests that Southwest Asian PPN dwellings probably consisted of nuclear households due to their adaptive advantage over extended households. He explains that smaller households focus on a reduced number of simultaneous tasks and are able to distribute spatially restricted resources more easily, with less conflict and jealousy.

Archaeological investigations have attempted to refine estimates of dwelling unit size for PPN villages (Table 4.7). Analyses of house size and the role of the household indicate that smaller, curvilinear dwellings, which usually comprise undifferentiated residential floor area, may have accommodated individual, pairs or smaller units of up to three people (Flannery 1972; 2002; Bar-Yosef 1998); whilst larger and rectilinear dwellings, which are often highly compartmentalised and contain considerable storage space, may have accommodated nuclear or extended families (Rollefson and Köhler-Rollefson 1989; Gebel and Hermansen 1999; Banning 2003; Byrd 2005a; Hemsley 2008; Rollefson and Kafafi 2013). Hemsley (2008) estimated a maximum of 46 sleeping occupants for the largest house at Basta (House I) based on an upper storey residential area covering the entire ground floor plan. However, this does not take into consideration access routes to ground floor/basement rooms and such large occupant numbers are highly improbable given the population density this would reflect.

Table 4.7. Dwelling unit size estimates for PPN central and southern Levantine villages.

Site	Period	Dwelling type	People/ dwelling	Reference
Jericho Netiv Hagdud	PPNA	Small, single-roomed structures	1-3	Hemsley 2008[a]
		Large, single-roomed and compartmentalised structures	4-9	
Jericho	MPPNB	Single storey pier houses	max: 5-11	
Basta	LPPNB	Large, central rooms as residential area	max: 4-8	
		2nd storey as residential area over entire ground floor area	max: 46	
'Ain Ghazal	PPNB-PPNC	Rectilinear houses	6	Rollefson and Köhler-Rollefson 1989[b]
Ba'ja	LPPNB	Rectilinear houses	8-10	Gebel and Hermansen 1999

a Based on maximum number of adults lying extended within dwellings.
b Based on estimated population (using van Beek's (1982) SPDC) and number of contemporaneously utilised houses (80% of 63 dwellings per hectare).

4.3.3 Population dynamics

A number of investigations have derived annual population growth rates for early village communities. Carneiro and Hilse (1966) and Hassan (1981) estimated a universal annual population growth rate of around 0.1% for non-industrialised, agricultural village populations; Bandy (2001) estimated a 0.08% annual growth rate for formative villages in the Titicaca Basin, Bolivia; and Drennan and Peterson (2008) estimated a 0.25% annual growth rate for communities undergoing the NDT in the Chifeng region of the Liao Valley, China, and in the Alto Magdalena, Colombia.

There have been two major attempts to estimate central and southern Levantine PPN population growth. Eshed *et al.* (2004) examined skeletal evidence from Natufian and Neolithic contexts to establish growth rates of 0.5% to 1% per annum, whilst Goodale (2009, p.160) estimated growth rates varying between -1.3% and 2.1% throughout the PPN. Kuijt (2008a, p.295) assessed population growth rates in relation to population size, population density and processes of human and settlement development throughout the NDT (Figure 4.7). His results suggest that population growth rates increased to around 1% per annum, following the development of agro-pastoralist economies during the MPPNB, then reduced to around 0.4% by the LPPNB, despite an increase in site density, stabilising at this level for the remainder of the PPN.

Deriving absolute population growth rates for PPN settlements is problematic for various reasons, including problems associated with dating and phasing; the limited number of sites containing consecutive phases; and difficulties with producing precise and accurate population size estimates.

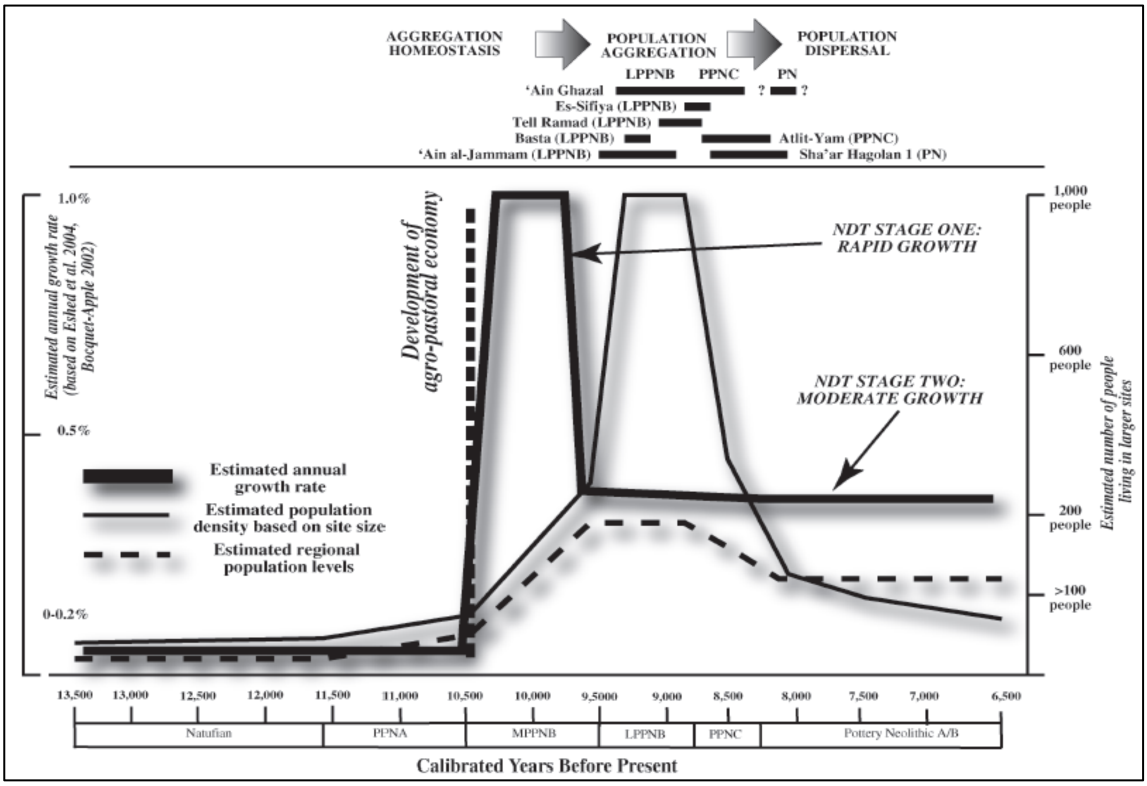


Figure 4.7. Population growth pattern during the NDT compared to population sizes and processes of socio-cultural development (Kuijt 2008a, p.295).

4.4 Limitations of existing methodologies and estimates

This summary of the main methodologies for estimating population parameters and the existing estimates for PPN central and southern Levantine villages highlights several limitations. Firstly, there are a limited number of sites for which absolute estimates exist, particularly relating to the number of people per dwelling and the amount of space per person. Secondly, due to methodological issues, investigations rarely attempt to produce absolute estimates and those that do emphasise their benefit for comparative analysis rather than as representations of actual population size. For this reason, methodologies and density coefficients are often insufficiently critically assessed prior to application and estimates usually display considerable ranges with little attempt at refinement. Thirdly, the majority of estimates are based on a very limited range of methodologies and a narrow selection of density coefficients derived from Southwest Asian ethnographic research conducted more than three decades ago. An assessment of the environmental context and the architectural and spatial characteristics of these ethnographic cases reveals that these are often unsuitable comparatives for PPN central and southern Levantine villages, particularly those with curvilinear architecture. If archaeologists are to develop more insightful reconstructions of social developments during the NDT, more empirically and statistically robust methodologies are required for estimating absolute population size, density and dynamics. In response to this need, a new method is developed in this investigation: the storage provisions formulae (SPF).

4.5 New method: the storage provisions formulae (SPF)

The storage provisions formulae (SPF) is a new method developed in this investigation that aims to estimate the resident population of a village based predominantly on empirical archaeological data. The formulae were derived from data produced by Hemsley (2008) (Appendix A). As part of her research into the multi-sensorial experience of central and southern Levantine PPN buildings, Hemsley (2008) employed a method for estimating the number of adult sleeping occupants per building. Using average personal sleeping space requirements of 1.24 m^2 for a 1.65 m tall person and 1.77 m^2 for a 1.83 m tall person, maximum occupant ranges were calculated per structure, factoring in hearths and surrounding activity zones, access routes and three potential amounts of annual personal storage allowance within the floor area (none; 0.46 m^3; 2 x 0.46 m^3) (Figure 4.8).

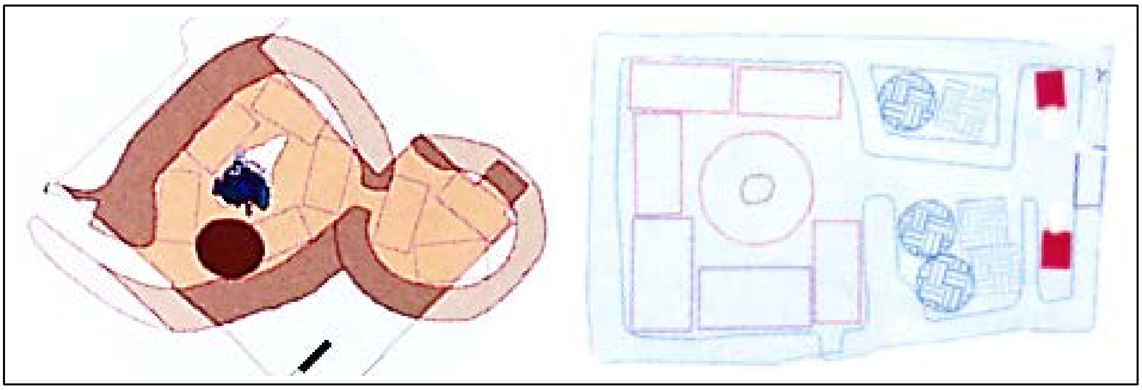


Figure 4.8. Examples of Hemsley's (2008) method for delineating space within PPN structures at Jericho. Left: PPNA - eight adults sleeping facing inwards (p.182); right: MPPNB - two 1.83 m tall and four 1.65 m tall adults sleeping facing inwards towards a hearth and surrounding activity area, with 0.46 m^3 annual personal storage within the floor area (p.246).

The human heights utilised in Hemsley's (2008, p.82) investigation represent the lower to upper end of the modern average adult height range. As the target population in this method relates only to adults, this method avoids making assumptions about the composition of the dwelling unit. However, there would certainly have been children present within these settlements, meaning that estimates based on the SPF may represent an underestimation of actual population size. Alternatively, animals may have occupied some of the residential area, particularly from the MPPNB with the increasing prevalence of domesticated animals, meaning that the SPF may overestimate the population size. It is important to highlight the potential impact of the presence of children and animals on the SPF population estimates. However, in this analysis, only the basic application of the SPF is explored with further work recommended to refine the method.

Storage quantification in Hemsley's (2008) analysis was based on average daily calorific requirements for physically active modern hunter-gatherer populations (c. 2,500 calories/day) and an estimated requirement of 221 kilos of grain per person per year based on ethnographic research into the percentage of diet comprising plant resources (c. 80%) and calorific content of these resources (1 kilo = 3,300 calories) (Hemsley 2008, pp.90-91). Ethnographic data relating to daily calorie intake in hunter-gatherer populations is considered directly applicable to prehistoric populations as sustainability requirements should have remained relatively constant. Assuming that grains were stored in a semi-clean state, Hemsley (2008, p.92) calculated that 0.33 m^3 of stored grains would be required to comprise 80% of an individual's total annual intake. Factoring in 25% wastage, she arrived at a final annual personal storage requirement of 0.46 m^3. Maximum provisions (2 x 0.46 m^3) accounted for the amount required to sustain an individual for a year, with additional quantities as a risk buffer and for seed for the following year (Hemsley 2008, p.89). This maximum amount is comparable to Kramer's (1982, p.121) estimate of stored requirements for a family of five to six people.

Consideration of storage allowance limits the maximum occupant number considerably (Hemsley 2008, p.141). The correlation between floor area and the mid-point of the maximum number of 1.65 m and 1.83 m tall sleeping occupants based on each of the three amounts of storage provision produces formulae that have the potential to directly calculate dwelling unit size from floor area (Figure 4.9).

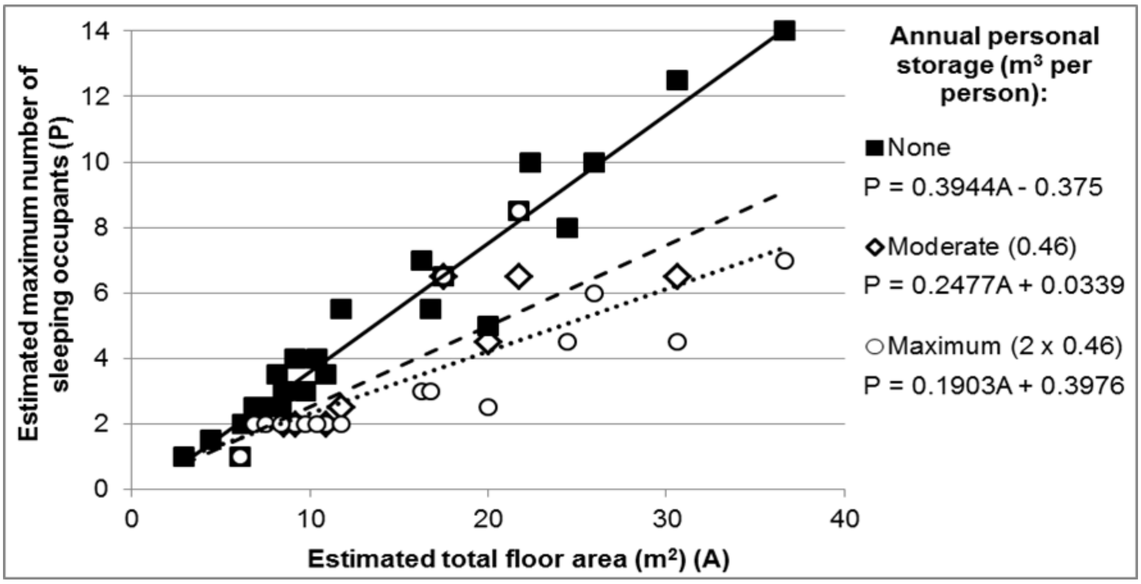


Figure 4.9. Correlation between floor area and the mid-point of the maximum number of 1.65 m and 1.83 m tall sleeping occupants based on three amounts of annual personal storage within the floor area. Data from Hemsley (2008) (Appendix A).

This presents an opportunity to develop a more empirically robust and systematic methodology for estimating the total (adult) population size and the number of people (i.e. adults) per dwelling. To estimate population size and people per dwelling via the SPF in this investigation, residential floor area is assigned as the A variable and suitable formulae are selected based on archaeological evidence for storage (or the potential for storage) within the residential floor area. At the micro-level, calculations of residential floor area are derived from the excavated evidence. Systematic estimates use constants derived from micro-level analyses.

4.6 Group size and cultural evolution

Cultural evolutionary theory is based on the notion that, over time, human socio-cultural developments, such as the emergence of agriculture or the rise of social inequalities, occur as a result of adaptation to non-cultural stimulus, such as population growth or climate change. Cultural evolutionary theory proposes that cultural developments are directional, progressing either through a process or via a sequence from simple to more complex (Feinman 2000, p.5). A widely accepted theory based on this premise is Fried's (1967) three-stage evolution from egalitarian to ranked, and eventually, stratified societies. Egalitarian societies are described as lacking inherited differences in wealth and status, and are commonly associated with hunter-gatherer communities; ranked or moderately stratified cultures are described as having inherited differences with the potential for generational status change and have been associated with small to medium-scale food producing economies; and highly stratified cultures are described as having inherited differences with little or no potential for generational status change and are associated with highly complex and diversified societies (Watts *et al.* 2016, p.228). Archaeological evidence for the PPN supports this theory of evolution, indicating a general shift from egalitarian to ranked or moderately stratified communities.

Theorist have explored different trajectories for this evolution. For example, early theorists explored unilinear evolution, whereby culture evolves from cumulative mastery of resources and technology through a prescribed set of stages (White 1959; Castro and Toro 2014). This theory was largely criticised for not accounting for the remarkable diversity in social systems and, as such, others sought to explain cultural development via multilinear evolution. Multilinear evolution explains diversity in cultural evolution as a process of local adaptation, in which cultural development is induced as a result of community members solving problems of daily life (Steward 1955). Local adaptations are argued to produce geographically localised cultures that prompt exchange and interdependence between communities adapted to, and harnessing the outputs of, their respective geographical zones (Barth 1956). Ultimately, groups that exploit a wider repertoire of food resources are said to gain a competitive advantage over nearby groups, further inducing geographically confined competitive developments in social organisation and technology (Read and LeBlanc 2003).

A key element of human socio-cultural evolution is group size (Oswalt 1976; Shennan 2001; Henrich 2004; Kline and Boyd 2010). There are two major theories that link changes in population size to socio-cultural evolution. The first relates to the relationship between groups and their environment, particularly in relation to food acquisition (Andersson and Read 2016). Johnson and Earle (2000, pp.24-31) explain the "primary engine" of subsistence intensification as the positive feedback between population growth, which expands the needs of a society, and technological developments that enhance resource exploitation. As the population increases, groups develop more complex food procurement strategies and technologies, indirectly inducing and/or increasing social complexity. This theory emphasises the role of population pressure and group adaptation on cultural complexity.

The second relates to what is defined as the "treadmill of cultural loss" (Kline and Boyd 2010), whereby highly creative individuals are required to counteract the loss of information that occurs through imperfect imitation of transmitted skills. The probability of selecting effective role models and the occurrence of highly creative individuals is argued to be higher in larger populations, enabling these communities to "outrun" culture loss (Shennan 2001; Henrich 2004; Kempe and Mesoudi 2014). This theory emphases the role of endogenous forces on increasingly complex social interactions and institutions (Andersson and Read 2016).

The directional and cumulative assumptions underlying cultural evolutionary theory and the widespread recognition of the link between group size and cultural evolution have lead some researchers to explore group size thresholds: that is, the size at which groups demonstrate evidence for certain socio-cultural developments. Group size thresholds are based on the notion that as groups increase in scale, organisational strategies shift, changing the way society functions in terms of the relationships between various social institutions (i.e. family and relationship networks, religion, education, economic activities and government). The importance of these social institutions is particularly emphasised in structural functionalist approaches, in which such institutions are considered to serve three core functions: i) to structure social relationships through role expectation; ii) to enable suitable people to adopt positions of power; and iii) to provide symbols, policies and ideologies that form the meanings and values underlying the social system (Verwiebe 2014). Some major elements of structural functionalism include, social inequality, interdependence, social cohesion and equilibrium.

Social inequality (i.e. unequal distribution of risks and rewards) is considered an important element of societies, as it provides motivation for people to act in order to gain rewards (i.e. wealth, status, power, etc.). This is both a manifestation and facilitator of social diversification, often linked to the division of labour. Durkheim (1893) refers to the division of labour in more complex societies (i.e. non hunter-gatherer) as representing “organic solidarity”, where diversity leads to interdependence between community members. This interdependence requires increasing specialisation (i.e. craft specialisation), ultimately leading to more complex, socially diversified and stratified (i.e. hierarchical) societies (Bodley 2003, p.55).

Theories relating to social cohesion are closely linked to those of scale (i.e. relative size) and scalar stress. The term “scalar stress” describes the processes of increased intra-group conflict resulting from a lack of cohesiveness and reduced quality in decision-making that occurs in larger groups (Johnson 1982). As group size approaches a critical level of scalar stress and the community is no longer able to manage as it once did, mechanisms are sought to promote social cohesion and prevent group fissioning, as often occurs within smaller-scale societies (Bandy 2004; Alberti 2014). Social cohesion is achieved by producing and maintaining positive membership attitudes and behaviours, and interpersonal interactions that promote group-level conditions (Friedkin 2004, p.410). Strategies for social cohesion are aimed at producing equilibrium in the social system, both internally, between interrelated sub-groups or social institutions, and externally, between the social system and the environment (Spencer 1898; Hackman and Vidmar 1970).

Although some emphasise the role of non-demographic factors (i.e. environmental risk and mobility) in cultural evolution (Vaesen *et al.* 2016), Johnson and Earle (2000, p.2) argue that “population growth is undeniably central to the process of sociocultural evolution, because of its clear consequences for how people meet their basic needs”. When exploring cultural evolution from early small-scale to complex societies, three common evolutionary processes emerge: intensified subsistence practices, political integration and social stratification. Based on the recognition of these key processes, this research focusses on the relationship between group size and developments relevant to the NDT: i) changing subsistence practices; ii) integrative and cohesive strategies aimed at reducing scalar stress in larger sedentary communities; and iii) increasing labour diversification and social complexity.

Extensive research has been conducted on the impact of group size on cultural complexity, particularly in hunter-gatherer groups (Oswalt 1976; Read 2008; 2012; Kline and Boyd 2010; Collard *et al.* 2013; 2016; Vaesen *et al.* 2016). Fewer studies have focussed on the relationship between group size and cultural evolution in non-industrialised, small-scale, food-producing communities, such as those which existed during the central and southern Levantine PPN. From these studies, several group size thresholds potentially relevant to this period have been proposed (Table 4.8). These thresholds are drawn from several ethnographic, historical and archaeological analyses of settlements undergoing the NDT, or exhibiting similar characteristics to PPN villages, throughout the world. These thresholds are based on various theories, including labour requirements relating to the primary mode/s of subsistence (Binford 2001); the potential mating network; and the size of land available for agriculture, pastoralism and hunting (Kuijt and Goring-Morris 2002, p.368).

The smallest group size threshold identified in this analysis relevant to the NDT relates to the transition from a mobile to a permanently settled community. This is often hypothesised to occur in populations of at least 25 people (Fletcher 1981; Binford 2001; Kuijt and Goring-Morris 2002; Bandy 2010). This minimum group size may be linked to the average number of families recorded in mobile communities (3-4 nuclear families) as opposed to early sedentary communities (perhaps 5-10 nuclear families) (Goring-Morris and Belfer-Cohen 2008, p.274).

The next level of thresholds relates to changes in subsistence from hunting and gathering to farming (i.e. the cultivation of wild plants) ($P \geq 50$) (Drennan and Peterson 2008), and, eventually, to fully agro-pastoralist strategies (i.e. relating to domesticated species) ($P \geq 100$) (Fletcher 1981; Kuijt and Goring-Morris 2002). In some cases, agricultural practices are present in populations that do not exceed these thresholds. The incidence of cumulative cultural evolution that occurs within extended labour networks could explain the presence of more developed processes than expected within some small settlements (Shennan 2001; Henrich 2004; Vaesen 2012). Indeed, within certain geographical settings, larger populations may be formed from networks of interactive subpopulations (Powell *et al.* 2009; Kobayashi and Aoki 2012).

Gallagher *et al.* (2015, pp.14220-14221) explored several models for the transition to farming, suggesting that farming has a greater probability of emerging within smaller communities, in which group cooperation is favoured over behavioural experimentation. Other studies have linked subsistence developments to larger populations, citing behavioural experimentation as a key element (Mesoudi 2011; Castro and Toro 2014; Gallagher *et al.* 2015). This, combined with the ability to select the most effective role models for skills transmission in larger groups (Andersson and Read 2016, p.272), is argued to increase domains of specialisation and diversification (Naroll 1956; Carneiro 1967). Boserup (1965) argues that maintaining these skills and producing further innovations would require ever larger labour units and networks, and more hierarchical organisational structures in which some community members attain power or higher status through highly specialised knowledge. As such, Boserup (1965) views population growth as an essential, if not sole, factor in increasing social complexity.

A further threshold relates to the role of the house and household in increasing social complexity. Kuijt and Goring-Morris (2002, p.368) suggest that group sizes of 100 to 750 people are common for southern Levantine sedentary farming and/or herding villages comprising potential house-based societies. These societies are based on the house as the fundamental organisational unit. These houses are often interpreted as representing household economic units that function within an overarching, supra-household economy (Gillespie 2007; Baird *et al.* 2016). The emergence of households as economic sub-units has been linked to increasing reliance on agricultural and pastoral activities, as farmers may have preferred to share produce with closely related individuals rather than with less productive neighbours (Wills 1992; Winterhalder 1990; Flannery 2002). In this way, thresholds relating to house-based societies may be closely linked to those relating to changing subsistence practices.

Ethnographic research has revealed that in populations of at least 127 people intra-village conflicts frequently arise (Chagnon 1980; Bowser 2000; Dunbar 2003; Alberti 2014, p.12) leading either to fissioning of communities into subgroups (i.e. 'daughter villages') (Bandy 2004, pp.323 and 330; 2006, p.233) or to the introduction of mechanisms for promoting social cohesion within larger groups (Kosse 1990, p.284; Hill and Dunbar 2003).

Mechanisms to facilitate greater social cohesion include:

- segmentation of the community into neighbourhoods (Düring 2013);
- an increase in economic independence of household units (Byrd 1994; Kuijt and Goring-Morris 2002);
- greater compartmentalisation within dwellings to alleviate stress associated with social crowding (Kuijt 2000);
- the maintenance of communal food-related activities (i.e. feasting) (Twiss 2008); and,
- the development of more formalised institutions for group decision-making, and ceremonial and ritual activities (Byrd 1994).

Within settlements of at least 250 people, it is suggested that individuals would be unable to maintain close personal relationships with all people causing the transition from egalitarian to more complex social structures (Forge 1972; Kosse 1990; Dunbar 1992; Bintliff 1999). Suggested indicators of increased social differentiation and complexity include: i) extensive food storage, which would have required some degree of management in terms of acquisition and distribution (Kuijt 2000); ii) differentiation of individuals at death, including variable association with grave goods or differential skeletal treatment; iii) variable structural form of, and differential and/or restricted access to, residential structures (Kuijt and Goring-Morris 2002, p.421); and iv) evidence for innovative technologies that would have required specialised knowledge, such as the manipulation of lithic material to produce rings and bracelets, or hydrological developments that enabled construction of water wells (Gebel and Bienert 1997; Galili and Nir 1993). More complex methods of communication and interaction would have been required to monitor community members within these larger sedentary populations. Efforts to foster cooperative relationships within such communities may be reflected by repeated symbolic representations and standardised ritual practices (Rosenberg and Redding 2002, pp.40-52).

At population levels of around 400, face-to-face communication becomes more difficult and it is argued that, in populations of such size, information may be regulated by a restricted number of authoritative individuals with decision-making powers ($P \geq 500$). In ethnographic contexts these roles are usually occupied by adult males (Naroll 1956, p.690; Kosse 1990, p.284). The presence of authoritative individuals may be indicated by notched and incised items that may have been formal markers for identification purposes (Edwards 2007, p.27). In addition, specialist skeletal treatment, such as skull plastering, may have been reserved for such individuals (Kuijt and Goring-Morris 2002). Rival authoritative individuals are suggested to occur within settlements of at least 1,500 people, giving rise to politically stratified communities (Alder 1990). Long-running walls which segment some settlements may indicate such rival or competing groups (Goring-Morris and Belfer-Cohen 2008, p.276).

Cross-cultural studies of non-hierarchical societies have revealed similar group size thresholds for specific developmental processes. Indeed, Johnson (1982) has identified a distinct pattern whereby group size thresholds in such communities often represent multiples of six times the average household size. However, in hierarchical communities, the relationship between group size and developmental processes is more varied, being largely dependent on environmental context and underlying cultural practices. PPN central and southern Levantine villages demonstrate increasingly hierarchical social structures. Therefore, an exploration of group size thresholds specifically founded on cultures undergoing the NDT, and in similar geographic settings if possible, has the potential to enable archaeologists to predict specific developmental processes based on estimated group size, and potentially to predict group size based on evidence for developmental processes. Despite the problematic nature of group size thresholds, this investigation seeks to explore the precise relationship between group size and socio-cultural developments that occurred during the PPN in the central and southern Levant. The more empirically and statistically robust population estimates produced in this investigation will facilitate this exploration.

Table 4.8. Hypothesised group size thresholds relevant to PPN villages.

Social state/condition	Group size threshold	References
Extended family nomadic tribal camp: southern Levant	10-30	Kuijt and Goring-Morris 2002, p.368
Transition to sedentary existence	≥ 25	Fletcher 1981; Binford 2001
Sedentary tribal hamlet: southern Levant	30-100	Kuijt and Goring-Morris 2002, p.368
Minimum village size	40	Bandy 2010, p.31
Initial farming village: China	≥ 50	Drennan and Peterson 2008
Largest hunter-gatherer group size based on mobility cost curves	100-300	Perlman 1985, p.42
Adoption of a fully sedentary, agro-pastoralist subsistence strategy	≥ 100	Fletcher 1981
Sedentary farming and/or herding village w/possible household units: southern Levant	100-750	Kuijt and Goring-Morris 2002, p.368
High probability of experiencing critical scalar stress (intra-village conflict)	≥ 127	Alberti 2014, p.12
Clan or regional group	≤ 150	Zhou *et al.* 2005, p.440
Fission/fusion: sectoring or introduction of mechanisms for social cohesion	≥ 150	Kosse 1990, p.284; Hill and Dunbar 2003
Size of neighbourhoods at PPN Çatalhöyük	150-250	Düring 2013
Large villages split into 'daughter' villages	170	Bandy 2004, pp.323 and 330
Intra-village conflicts frequently arise (scalar stress)	≥ 200	Chagnon 1980; Bowser 2000
Unable to maintain close personal relationship with all people	≥ 250	Forge 1972; Kosse 1990; Dunbar 1992; Bintliff 1999
Predominantly egalitarian communities develop more complex social structures	≥ 350	Forge 1972
Face-to-face interaction with all people	≤ 400	Kosse 1990, p.284
Development of more complex, hierarchical society: New Guinea	≥ 400	Kosse 1990, p.283
Transition from village to town	≥ 400	Murdock and Provost 1973
More casual relationships	400-600	Forge 1972; Kosse 1990; Dunbar 1992; Bintliff 1999
Demographically stable community - intra-community mate-exchange: Chacoan region	≥ 475	Mahoney 2000, p.20
Rise of authoritative officials and development of polities	≥ 500	Naroll 1956, p.690
Adult males with decision-making power regulate information	500-2500	Kosse 1990, p.284
Politically non-stratified communities	≤ 1500	Alder 1990
Maximum pueblo village size: American Southwest	≤ 2000-3000	Kosse 1990, pp.282-283
Development of complex society	≥ 2000	Kosse 1990, p.283
Community members able to monitor each other through social networks	≤ 2500	Kosse 1990, p.284
Need for innovative farming methods (i.e. specialised pastoralism, flood-plain cultivation)	3000-5000	Bogaard and Isaakidou 2010
Largest Southwest Asian Neolithic settlement population estimate: Çatalhöyük	3500-8000	Düring 2013, p.35

4.7 Summary

Population size, density and dynamics are essential for reconstructing early village development. Commonly utilised methods for estimating population parameters of formative, pre-industrial villages include the housing unit method (HUM), residential area (RADC) and settlement population density (SPDC) coefficient methods, and allometric growth formulae (AGF). An additional method established in this analysis is the storage provisions formulae (SPF), based on data produced by Hemsley (2008), which equate available residential floor area to a maximum number of sleeping occupants.

These methods can be applied at the micro-level and systematically to multiple sites. For each of these methods, there are a series of theoretical and methodological considerations, particularly relating to the identification of dwellings and residential or sleeping area; the composition of the dwelling unit; site extent estimates; the representativeness of structural density in the excavated area; and the degree of structural and site contemporaneity.

In this analysis, a methodology is explored for determining structural contemporaneity values based on span estimates for building use-life and phase length (Varien *et al.* 2007). The use of Bayesian chronological modelling for producing more precise span estimates is explored.

A summary of existing estimates of population parameters for PPN central and southern Levantine villages has highlighted some of the theoretical and methodological limitations, providing support for the exploration of more empirically and statistically robust methods in this investigation. Accurate and precise estimates will enable more meaningful analyses of the relationship between PPN village group size and cultural evolution during the NDT.

5 Methodology

This chapter describes the selection and preparation of data, including criteria for inclusion of sites within the PPN village database; estimates of total site extent; criteria for the selection of sites for micro-level assessment; criteria for identification of (potential) dwellings and residential area; and the process for digital transcription of site plans. This is followed by a detailed explanation of the methods employed in micro-level analyses and for systematic reconstruction of population parameters of all sites in the PPN village database.

5.1 Data selection and preparation

5.1.1 The PPN village database

The PPN village database (Appendix D.1) includes permanently and predominantly permanently settled, open air clusters of structures, including dwellings and associated non-residential structures and areas. The database does not include rockshelter or cave sites (i.e. Iraq ed-Dubb) (Kuijt 2004a); sites which have been interpreted as principally for ceremonial, ritual or mortuary purposes (i.e. Kfar HaHoresh) (Barker 2012), or for other communal or production activities (i.e. WF16) (Finlayson *et al.* 2012); or ephemeral or seasonal camps, whose inhabitants were either predominantly mobile or would have maintained permanent accommodations elsewhere (i.e. Nahal Issaron) (Barzilai and Goring-Morris 2007).

The initial dataset was based on Coward's (2010) database of Near Eastern prehistoric archaeological sites developed between 2005 and 2008 for the British Academy Centenary Project 'From Lucy to Language: the archaeology of the social brain'. Potential village sites were selected from this database, with additional sites identified through extensive examination of site reports, publications, and online resources and databases (i.e. the Radiocarbon CONTEXT database, MEGAJordan and ex oriente). Those which contained village characteristics as outlined in the introduction were classed as villages in this analysis.

The village database includes PPN period, identification (ID) numbers, site name, site type based on the newly proposed classification system (see Section 8.8), predominant architectural form (i.e. curvilinear or rectilinear), estimated total site extent, latitude and longitude coordinates, country of location and references. ID numbers are assigned first according to PPN period, then by site type and alphabetical order of site names. ID numbers are utilised in all tables, graphs, site distribution maps (created in ArcMAP10) and statistical analyses (conducted in SPSS).

5.1.2 Estimates of total site extent

Total site extent estimates are used in several methodologies for estimating population. As such, the accuracy of site extent estimates needs to be addressed. It is generally recognised that there is a tendency to overestimate site sizes based on artefact scatters and to not clearly consider the extent of the habitable area in relation to disused open area or space designated for non-residential purposes, such as farming or communal activities (Goring-Morris and Belfer-Cohen 2008, p.270). Inflated site extent estimates will result in inflated population size estimates.

Total site extent estimates were derived from publications for 79 of the 106 villages and village phases. Where a general site size and minimum or maximum extent is published (i.e. “a small site of perhaps 1-2 ha”), the minimum suggested extent is utilised. Where the published site extent is excessive (i.e. as for LPPNB Aviel: 50 ha and Kharaysin: 36 ha) or includes multiple periods (i.e. Tell Eli and Tell Labwé), a moderated site extent is utilised (Tables 5.1-5.3; Figure 5.1). This extent was determined via analysis of (1) published site extents per period and predominant architectural form; (2) site extents for preceding and succeeding phases (where present); (3) the extent of nearby villages; and (4) any additional information relating to site extent. The same method was utilised to establish site extent for the 27 villages/village phases for which site extent estimates were not published. There is potential for circularity in these suggested site extent estimates, as these are based on current knowledge and theory relating to site extent per period, site type and location. However, this is mitigated against by the assessment of additional site-specific information relating to site size.

For villages assessed at the micro-level that demonstrate evidence for considerable uninhabited space within the estimated total site extent (i.e. Ghwair I, LPPNB el-Hemmeh, Basta and Ba’ja), a reduced site extent was utilised in calculations of population size to avoid overestimation. This reduced extent attempts to account for only the habitable area. The original estimated site extent was utilised in all subsequent micro-level and systematic analyses. Thus, constants and proportions derived at the micro-level and applied systematically to all sites in the PPN village database inherently account for uninhabited space.

Table 5.1. Reduced and moderated site extents.

Site name	Period	Site extent (ha) *Estimated*	*Moderated/ Reduced*	Reference
Huzuq Musa	PPNA	1-2	1	Nadel and Rosenberg 2013
Tell Aswad 1A	PPNA	≥ 1	1	Moore 1983
Tell Aswad 1B	EPPNB	≥ 1	1	Moore 1983
Horvat Galil	EPPNB	≤ 2	1	Hershkovitz and Gopher 1988
Qminas	LPPNB	≤ 2	1.5	Masuda and Sha'ath 1983
Tell Aray	LPPNB	≥ 5	5	Tsuneki 2012
Tell 'Ain el-Kerkh/II	LPPNB	≥ 16	16	Tsuneki 2012
Sites assessed at micro-level				
Ghwair I	MPPNB	1.2-1.45	1.325	Simmons and Najjar 2003
El-Hemmeh	LPPNB	1	0.8	Rollefson 1999
Basta	LPPNB	12-14	13	Kuijt 2000
Ba'ja	LPPNB	1.2-1.5	1.35	Gebel 2003

Table 5.2. Site extents per period and architectural form.

	Statistics: N *Valid*	*N Missing*	*Mean*	*Median*	*Minimum*	*Maximum*
Period						
PPNA	16	2	.47	.20	.05	2.50
EPPNB	6	3	.60	.65	.10	1.00
MPPNB	21	7	1.56	.50	.06	5.00
LPPNB	24	8	5.34	4.50	.30	16.00
PPNC	12	7	4.18	4.00	1.00	8.00
Predominant architectural form						
Curvilinear	26	7	.39	.20	.05	2.50
Rectilinear	49	15	4.28	3.00	.25	16.00
Unknown	4	5	.55	.50	.20	1.00

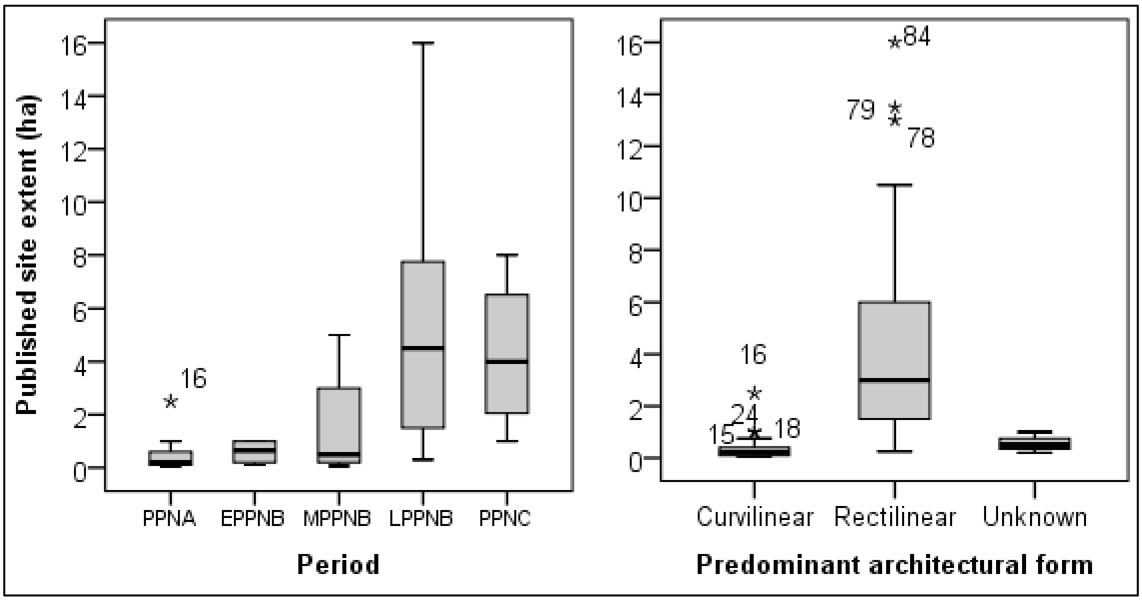


Figure 5.1. Site extents per period and architectural form (* 16: Jericho; 15: Huzuq Musa; 18: Tell Aswad IA; 24: Tell Aswad IB; 78: Basta; 79: Beisamoun; 84: Tell 'Ain el-Kerkh/II).

Table 5.3. Suggested site extents for sites of unknown size.

ID	Site name	Period	Predominant architectural form	Site size per period (ha)		Site size per predominant architectural form (ha)		Size of nearby sites	Additional information/ References	Suggested site size (ha)
				Mean	*Median*	*Mean*	*Median*			
3	Borj Barajne	PPNA	Curvilinear	0.47	0.20	0.39	0.20	-	(Copeland 1991)	0.20
5	El Aoui Safa	PPNA	Curvilinear	0.47	0.20	0.39	0.20	-	(Coqueugniot and Anderson 1996)	0.20
22	Motza VI	EPPNB	Curvilinear	0.60	0.65	0.39	0.20	-	EPPNB phase up to 2 m thick; at least 3 occupations (Khalaily *et al.* 2007)	0.50
23	Mujahiya	EPPNB	Curvilinear	0.60	0.65	0.39	0.20	-	"Small"; possibly ≤ 2 ha (Gopher 1990)	0.50
26	Tell Qarassa	EPPNB	Rectilinear	0.60	0.65	4.28	3.00	-	(Ibañez *et al.* 2010)	1.00
33	Jebel Ragref	MPPNB	Curvilinear	1.56	0.50	0.39	0.20	'Ain Abu Nekheileh (2 km): 0.12; Jebel Arqa (27 km): 0.2; Jebel Salaqa (33 km): 0.1	"Small" bead production site; similar to Jebels Arqa, Rabigh and Salaqa (Fabiano *et al.* 2004)	0.15
35	Shkārat Msaied	MPPNB	Curvilinear	1.56	0.50	0.39	0.20	Adh-Dhaman I (24 km): 0.2 Beidha (11 km): 0.2 Ghwair I (21 km): 1.325	0.1 ha of architecture (Kinzel 2013)	0.20
36	Tell Eli IV	MPPNB	Curvilinear	1.56	0.50	0.39	0.20	-	10 ha includes all periods (Simmons 2007)	2.00
39	'Ail IV	MPPNB	Rectilinear	1.56	0.50	4.28	3.00	Jebel Arqa (28 km): 0.2 Jebel Rabigh (17 km): 0.06 Jebel Salaqa (22 km): 0.1	A "major" site; compared to Ba'ja (1 ha), Beidha (0.2 ha) and Shkārat Msaied (0.2 ha) (Gebel 2008; 2010)	1.00
41	Beisamoun	MPPNB	Rectilinear	1.56	0.50	4.28	3.00	-	Less than LPPNB Beisamoun (13.5 ha); similar to MPPNB Tell Aswad (5 ha) (Bocquentin *et al.* 2011)	5.00
46	Motza V	MPPNB	Rectilinear	1.56	0.50	4.28	3.00	Abu Gosh (6 km): 0.25 Jericho (30 km): 4	(Khalaily *et al.* 2007)	1.00
55	Tel Roim West V	MPPNB	Unknown	1.56	0.50	0.55	0.50	-	PPNC Tel Roim West IV = 1 ha (Nadel and Nadler-Uziel 2011)	0.50
57	'Ail IV	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	'Ain Jamam (19 km): 7	A "major" site; similar to Ba'ja (1.35 ha), Beidha (0.3 ha) and Shkārat Msaied (0.2 ha) (Gebel 2008; 2010)	2.00
62	Motza Tahtit	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	Jericho (31 km): 4	3 LPPNB phases; "almost certainly abandoned" by PPNC (Mizrahi 2015)	2.00

ID	Site name	Period	Predominant architectural form	Site size per period (ha)		Site size per predominant architectural form (ha)		Size of nearby sites	Additional information/ References	Suggested site size (ha)
				Mean	*Median*	*Mean*	*Median*			
66	Tell Eli III	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	-	10 ha includes all periods (Simmons 2007)	5.00
68	Tell Labwé	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	-	12 ha includes PN (Khalidi *et al.* 2013)	5.00
81	Kharaysin	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	-	36 ha scatter likely due to deflation (Thorpe and Edwards 1986)	10.00
85	Wadi Shu'eib	LPPNB	Rectilinear	5.34	4.50	4.28	3.00	-	LPPNB/PPNC: 14-30 acres (5.5-12 ha); larger than Jericho (LPPNB: 4 ha); smaller than 'Ain Ghazal (LPPNB: 10 ha) (Simmons *et al.* 2001)	8.00
86	Aviel	LPPNB	Unknown	5.34	4.50	0.55	0.50	-	50 ha scatter (Barkai and Biran 2011)	3.00
87	Es-Sayyeh	LPPNB	Unknown	5.34	4.50	0.55	0.50	-	10 ha includes all periods; occupied area "much smaller" (Kafafi *et al.* 1999)	3.50
91	Hagoshrim VI	PPNC	Rectilinear	4.18	4.00	4.28	3.00	Beisamoun (11 km): 7 Tel Roim West IV (10 km): 1	8 ha includes PN levels; a "major" site (Rosenberg and Getzov 2006)	3.50
94	Tell Eli III	PPNC	Rectilinear	4.18	4.00	4.28	3.00	-	10 ha includes all periods (Simmons 2007)	3.50
95	Tell Labwé	PPNC	Rectilinear	4.18	4.00	4.28	3.00	-	12 ha includes PN (Khalidi *et al.* 2013)	3.50
98	Tell Teo	PPNC	Rectilinear	4.18	4.00	4.28	3.00	Beisamoun (9 km): 7 Tel Roim West IV (23 km): 1	(Horwitz and Ducos 2005)	3.50
100	Wadi Shu'eib	PPNC	Rectilinear	4.18	4.00	4.28	3.00	-	LPPNB/PPNC: 14-30 acres (5.5-12 ha); smaller than 'Ain Ghazal (PPNC: 8 ha) (Simmons *et al.* 2001)	6.00
105	Es-Sayyeh	PPNC	Unknown	4.18	4.00	0.55	0.50	Tell Abu es-Sawwan (10 km): 5	10 ha includes all periods; occupied area "much smaller" (Kafafi *et al.* 1999)	2.00
106	Wadi Fidan C	PPNC	Unknown	4.18	4.00	0.55	0.50	-	(Colledge 2001)	1.50

5.1.3 Selection of sites for micro-level analysis

Eleven villages were selected for micro-level analysis (Figure 5.2) based on the following criteria:

- clear and well-defined site plans enabling identification and measurement of assessable area and different aspects of the built environment;
- detailed excavation reports containing interpretation of archaeological features;
- clear evidence for, and interpretation of, residential structures enabling quantification and measurement of (potential) dwellings and residential area;
- justifiable dating of the site and its phases to cultural-historical periods.

These sites include 15 phases. Unfortunately, due to the limited spatial excavation of EPPNB and PPNC sites, these periods are not represented.

	PPNA	EPPNB	MPPNB	LPPNB	PPNC
Nahal Oren	▨				
Gilgal I	▨				
Netiv Hagdud	▨				
El-Hemmeh	▨			▨	
Shkārat Msaied			▨		
Beidha			▨ ▨ ▨	▨	
Ghwair I			▨		
Wadi Hamarash I			▨		
‘Ain Abu Nekheileh			▨		
Basta				▨	
Ba’ja				▨	

Figure 5.2. Sites selected for micro-level analysis.

5.1.4 Criteria for identification of (potential) dwellings and residential area

Dwellings are defined as structures in which people slept. Residential area in this investigation denotes (potential) sleeping area. Identification of dwellings and residential area is based on archaeological interpretations provided in publications and site reports. All interpretations of the excavators and report writers are accepted as correct. Where interpretation is unavailable, (potential) dwellings and residential area are distinguished based on the presence of a combination of interior features, including hearths, plaster or clay flooring and sleeping platforms or compartments; in situ artefacts relating to food storage, processing, preparation and consumption; and architectural elements that show strong similarities to previously identified dwellings, including size, construction materials, morphology and the potential function of associated architectural features (i.e. annexes for cooking and storage) (Watson 1978; Kramer 1982; Byrd 2002; 2005a). Where upper storey area exists, this is usually interpreted as residential area (Kuijt 2000; Byrd 2005a). Identification of dwellings and residential area is difficult and several identifications are hypothetical. There is always a margin of error when attempting to produce precise estimates from such data. However, attempts have been made to produce the most accurate estimates given the data available.

5.1.5 Transcription of site plans

Accurate area measurements are required for all micro-level methodologies. Existing site plans were transcribed using ArcMAP10. Images of site plans were imported into the ArcMAP10 interface. The map unit was set to metres, allowing the scale bar on the original site plan to be georeferenced to the correct length. Shapefiles were created to measure each archaeological feature (Table 5.4).

Table 5.4. Explanation of shapefiles and their use in micro-level methodologies.

Shapefile	Polygon description	Use
Potential dwellings	Encompasses the total area of potential dwellings including outer walls and clearly associated annexes. Where dwellings share an outer wall, the polygon border follows the midpoint of the wall to avoid doubling-up on area measurements. Where a dwelling floor exists with no/limited evidence for a wall, a hypothetical wall outline is drawn based on the average wall width within the site plan.	Dwelling identification for the HUM, SPF, RADC, AGF1, and SPDC.
Built (roofed) floor area	Follows the inside of the building wall and excludes built-in features identified in published site plans (i.e. cists and steps). The polygon border crosses between vertices of the inside of the wall on both sides of a doorway or gap.	To calculate floor area and proportions relating to floor area for the RADC, SPF and AGF1.
Potential upper storey residential built floor area	Where evidence exists for upper storey floor area, this is usually suggested to comprise residential area. Polygons are drawn as described for 'built floor area'.	
Potential residential built area	Encompasses the built area in which people probably slept, including walls and any built-in features.	To calculate residential area (and proportions of) for the HUM, RADC, SPF and AGF1.
Potential non-residential built area	Encompasses the built area which was probably not utilised for sleeping, such as workshops, storage facilities and other non-residential structures.	To calculate built area (and proportions of) for the HUM, RADC and AGF1.
Assessable area	Follows the boundary of the assessable area. Baulks, insufficiently described areas and unassessable areas () are subtracted from the total assessable area prior to assessment.	To calculate the proportion of site assessable for use in all methodologies.

Additional polygon shapefiles

Building walls	Potential upper storey non-residential built floor area
Building walls: lower storey	Corridors or passageways
Built-in features	Steps

5.2 Micro-level estimates

Methods for estimating population parameters at the micro-level include the housing unit method (HUM), the residential area density coefficient method (RADC), the storage provisions formulae (SPF), the allometric growth formulae derived by Naroll (1962) (AGF1) and Wiessner (1974) (AGF2), and the settlement population density coefficient method (SPDC). For each method, there are a number of sub-methods which enable the calculation of a range of demographic data for further analysis and for systematic reconstruction of population parameters of sites in the PPN village database (Table 5.5).

5.2.1 Methodological considerations and assumptions

The following basic assumptions and processes are applied for all methods:

1. The assessable area is considered representative of the total site, unless there is sufficient evidence to suggest otherwise. This evidence could include dwelling clusters, variable structural layout in different areas, and disused areas or corridors between structures indicative of sectoring into potential neighbourhoods; unsustainable structural density in the excavated area; or large open and communal areas in the excavated area. Where this occurs, a reduced site extent is used in calculations of population size to avoid overestimation (i.e. Ghwair I, LPPNB el-Hemmeh, Basta and Ba'ja).

2. The term 'residential area' equates to (potential) sleeping area.

3. The terms 'built floor area' and 'roofed floor area' are interchangeable.

4. Where multiple storeys are present, upper storeys are usually assumed to comprise residential area. Both ground floor and upper storey areas are included in measurements of residential and non-residential built and floor area. 'Built area' measurements are based on ground floor built area only in order to calculate proportions in the assessable area, which are used to establish proportions in total site extent for use in systematic methodologies.

Table 5.5. Micro-level methodologies: outputs and data required.

Method	Direct estimates produced									Indirect estimates and additional demographic data produced			
	Population size	People per dwelling	People per hectare	Initial growth index	Total number of contemporaneous dwellings	Total contemporaneous residential floor area	Total built floor area	Built floor area per person	Residential floor area per person	People per dwelling	People per hectare	Residential floor area per person	Population growth rate
HUM	✓				✓					✓	✓	✓	✓
RADC	✓					✓				✓	✓	✓	✓
SPF	✓	✓								✓	✓	✓	✓
AGF1				✓			✓	✓	✓				
AGF2				✓									
SPDC	✓		✓							✓		✓	✓

Method	Indirect estimates and additional demographic data produced — *Proportion of:*												
	residential built area in assessable area	residential built area in built area	residential built area in assessable area	residential floor area in built area	residential floor area in assessable area	contemporaneous residential built area in assessable area	contemporaneous built area in assessable area	contemporaneous residential floor area in assessable area	built floor area in built area	built floor area in assessable area	contemporaneous built floor area in assessable area	Evaluation of common density coefficients	Evaluation of existing formulae
HUM	✓	✓	✓			✓	✓		Not method specific			✓	
RADC	✓			✓	✓		✓	✓				✓	
SPF													
AGF1													✓
AGF2													✓
SPDC												✓	

Method	Data required																
	Assessable area	Total site extent	Proportion of area assessable	Contemporaneity value	Residential built area	Built area	Number of dwellings	Nuclear family sizes*	Total residential floor area	Residential floor area per person*	Total contemporaneous residential floor area	Mean residential floor area of complete dwellings	Total number of contemporaneous dwellings	Population estimate	Total built floor area	Proportion of residential floor area in built floor area	Population densities*
HUM	✓	✓	✓	✓	✓	✓	✓	✓									
RADC	✓	✓	✓	✓		✓			✓	✓							
SPF											✓	✓	✓				
AGF1														✓	✓	✓	
AGF2		✓												✓			
SPDC		✓												✓			✓

* Suggested values based on ethnographic, archaeological and experimental research.

5.2.2 Calculating upper storey floor area

Upper storey evidence is usually not sufficient to establish upper storey floor area. Therefore, a methodology was derived for calculating upper storey floor area based on the substantial second storey evidence at Beidha Subphase C2. Byrd (2005a, p.85) interprets all corridor buildings at Beidha as “primarily, if not exclusively, two-storey” based on upper storey evidence in five structures (Buildings 3-5, 14 and 73) and comparable ground floor plans throughout. As such, all Beidha corridor buildings are considered two-storey in this investigation.

To calculate upper storey floor area in structures with insufficient upper storey evidence, the three structures (Buildings 3, 14 and 73) that demonstrate the best preserved second storey evidence were analysed to determine the potential proportion of floor area in the upper storey interior area (Table 5.6). Internal walls, built-in features and a hypothesised 60 cm^2 passage between the lower and upper floors comprised around 17.5% of the upper storey interior area of these buildings. The remainder of the area was considered potential upper storey floor area. For sites and structures where upper storey floor area could not be determined directly, the total upper storey interior area was estimated based on the internal boundary of ground floor external walls. The proportion of upper storey interior area comprising internal features (17.5%) was then deducted from this area to calculate potential upper storey floor area.

Table 5.6. Beidha Subphase C2 structures assessed to determine the proportion to deduct from upper storey interior area to calculate potential upper storey floor area.

Building	**Total potential upper storey interior area**	**Area to deduct from upper storey interior area**						**Potential upper storey floor area**
		Interior walls and built-in features		Suggested passage between lower and upper storey		Total		
	m^2	*m^2*	*%*	*m^2*	*%*	*m^2*	*%*	*m^2*
3	21.79	2.8	12.85	0.6	2.75	3.40	15.60	18.39
14	15.23	1.15	7.55	0.6	3.94	1.75	11.49	13.48
73*	16.06	3.44	21.42	0.6	3.74	4.04	25.16	12.02
Mean							**17.42**	

* Marginally incomplete structure measures 13.10 m^2. Hypothetical boundary drawn in southwest corner to represent complete structure measuring 16.06 m^2.

5.2.3 Estimating structural contemporaneity: building use-life analysis and Bayesian chronological modelling

Structures identified within each site often appear to have been occupied contemporaneously. However, in reality, what we actually see in the archaeological record may have been produced by entirely unconnected human activities separated by tens to hundreds of years (Kuijt 2008a). Therefore, to avoid overestimating population size at any one point, estimates of the total number of dwellings, total residential floor area and area proportions require adjustment for structural contemporaneity. For the PPN village of ‘Ain Ghazal, Rollefson and Köhler-Rollefson (1989) suggested that 80% of the structures were occupied contemporaneously. In this investigation, a more empirically robust method for determining contemporaneity is employed. Used by Varien *et al.* (2007), this method calculates the proportion of structures that were contemporaneously occupied (herein referred to as a ‘contemporaneity value’) by dividing the average building use-life for a particular phase by the length of that phase.

Estimates of building use-life and phase (or subphase) length were derived from chronological information relating to stratigraphic sequences; building use-life estimates of comparable structures derived from archaeological, ethnographic and experimental research (Table 5.7); and Bayesian chronological modelling.

Table 5.7. Building use-life estimates based on archaeological, ethnographic and experimental research.

Predominant construction material	Additional information	Building use-life (years)	References
Earthen/light organic	Without maintenance With maintenance	6-15 15-45	Cameron 1990; Reynolds 1995; Diehl 2001; Ortman *et al.* 2007; Arnoldussen 2008; Varien 2012
	PPNA granaries	< 50	Kuijt and Finlayson 2009
Masonry *(all maintained)*	Neolithic Çatalhöyük	50-100	Hodder and Cessford 2004; Cessford 2005; Matthews 2005
	PPNB-PPNC ‘Ain Ghazal	≤ 100	Rollefson and Köhler-Rollefson 1989
	Ancient Southwest America	60	Ahlstrom 1985

Suggested building use-life (years)			
		Maintenance	
Construction	*Minimal*	*Moderate*	*Considerable*
Earthen	6-15	15-35	35-50
Earthen/masonry	10-35*	35-55	55-75
Masonry	20-50	50-75	75-100

* Use-life values based on the midpoint of the preceding and succeeding construction types (all values rounded to nearest 5).

Bayesian chronological modelling was conducted in the online programme OxCal v.4.2.4 (see the OxCal online manual for detailed user instructions) (Bronk Ramsey 1995; 2001; 2005; 2009; Bayliss *et al.* 2011). Radiocarbon dates were calibrated using the currently internationally accepted atmospheric calibration curve for the Northern Hemisphere (IntCal 13) (Reimer *et al.* 2013).

Dates were statistically assessed to determine potential outliers for removal prior to analysis. Chi squared tests (χ^2; Ward and Wilson 1978) were conducted on combined sets of radiocarbon dates ordered by phase/subphase in descending chronological order of the earliest calibrated date ranges. Where resulting ‘T’ values were higher than the threshold based on the 5% confidence limit (given in brackets), this indicated one or more stratigraphically divergent dates. Bayesian chronological modelling of the lower and upper occupation boundaries (i.e. ‘start’ and ‘end’ dates) based on the same ordering as per the χ^2 test revealed which dates were divergent.

Modelled date ranges are given as posterior density estimates using their 95.4% probability ranges and are indicated using italics, following the conventions defined by Millard (2014, p.557). Model index agreement values less than the agreement threshold (A ≤ 60%) highlight statistical outliers. The characteristics of these outliers were assessed to determine whether they represent residual or intrusive samples and could, thus, be removed from the sequence. Convergence values (C) were also assessed to determine whether the models were stable. A convergence value of greater than 95% indicates stability.

‘Phase’ or ‘sequence’ models were applied to the refined datasets to calculate start and end dates, and to estimate occupation span, subphase length and building use-life. In the OxCal online manual, ‘phases’ are defined as “groups of events which are all from one coherent group in some context but for which there is no information on the internal ordering” (Bronk Ramsey 2005). Phase models are suitable for datasets which do not have clear phasing or subphasing information, where the internal ordering of dates is unknown within a phase or where radiocarbon dates are not in chronostratigraphic order. ‘Sequences’ are defined as “groups of events or phases which are known to follow one after another with no possibility of overlap” (Bronk Ramsey 2005). Sequence models are suitable for datasets which contain clear phasing and subphasing information and where radiocarbon dates conform to the stratigraphic sequence. A combination of phase and sequence models is usually employed within each overall model.

Bayesian models can be constructed to produce ‘transition’ or ‘start’ and ‘end’ dates depending on the stratigraphic relationships between phases/subphases. ‘Gap’ periods can be inserted where phases/subphases have not been directly dated (i.e. Beidha Subphases B1 and C1) (Figure 5.3). Where more than one structure occurs within a phase/subphase, individual ‘building phase’ models can be grouped within overall ‘phase/subphase building phase’ models to allow for potential overlap between the dates of the structures within these phases (as conducted for Netiv Hagdud, Shkārat Msaied, Beidha, ‘Ain Abu Nekheileh, Basta).

```
Plot(“Beidha”)
 {
  Sequence(“Beidha”)
  {
   Boundary("Start Subphase A1");
   Sequence("Subphase A1")
   {
    Phase("Subphase A1 Buildings")
    {
     Phase("Building 18")
     {
      R_Date("K1086", 8940, 160);
      R_Date("P1381", 8765, 102);
      Span("Span Building 18");
     };
     Phase("Building 48")
     {
      R_Date("K1410", 8850, 150);
      R_Date("K1411", 8770, 150);
      R_Date("K1412", 8720, 150);
      Span("Span Building 48");
     };
    };
    Span("Span Subphase A1");
   };
   Boundary("Transition Subphase A1/A2");
   Sequence("Subphase A2")
   {
    Phase("Subphase A2 Buildings")
    {
     Phase("Building 54")
     {
      R_Date("K1082", 8710, 130);
      R_Date("P1378", 8715, 100);
      Span("Span Building 54");
     };
     Phase("Building 74")
     {
      R_Date("K1083", 8640, 160);
      R_Date("GrN5136", 8810, 50);
      Span("Span Building 74");
     };
    };
    Span("Span Subphase A2");
   };
   Boundary("End Subphase A2");
   Gap("Gap Subphase B1", 30);
   Boundary("Start Subphase B2");
   Sequence("Subphase B2")
   {
    Phase("Building 26")
    {
     R_Date("BM111", 8790, 200);
     R_Date("K1084", 8730, 160);
     Span("Span Building 26");
    };
    Span("Span Subphase B2");
   };
   Boundary("End Subphase B2");
   Gap("Gap Subphase C1", 70);
   Boundary("Start Subphase C2");
   Sequence("Subphase C2")
   {
    Phase("Building 8")
    {
     R_Date("P1382", 8892, 115);
     R_Date("K1085", 8550, 160);
     Span("Span Building 8");
    };
    Span("Span Subphase C2");
   };
   Boundary("End Subphase C2");
   Span("Span Beidha");
  };
 };
```

Figure 5.3. Example of OxCal code for chronological modelling of boundary (start/transition/end) dates and span estimates for PPN Beidha.

5.2.4 Housing unit method (HUM)

The housing unit method (HUM) derives total population based on a total number of dwellings and an ethnographically derived value for the number of people per dwelling. This method requires consideration of factors influencing the number of people per dwelling, such as household composition, the size and layout of residential architecture and interior features, cultural norms and preferences, settlement and subsistence type, social stratification, and economic status (see Section 4.1.1). Ethnographic studies of dwelling unit sizes in villages with similar characteristics to those of the PPN central and southern Levant range from around 4.3 to 8.75 people (see Table 4.1). The majority of archaeological investigations propose a value of around five to six people per dwelling based on the theory that Neolithic dwellings were inhabited by nuclear families and ethnographic analysis of nuclear family sizes in Southwest Asia (Sweet 1960; Haviland 1972; Kramer 1982; Düring 2001; Byrd 2002). To test the theory that nuclear families formed the predominant dwelling unit type, minimum, average and maximum family sizes of three, 5.5 and eight people are utilised in this investigation.

The basic equation for deriving population estimates via the HUM is as follows:

$$\text{Total population} = \text{number of dwellings} \times \text{number of people per dwelling}$$

The total number of dwellings is calculated via three methods: each produces the same estimate as they are all based on the same fundamental data (i.e. measurements and area proportions derived from the site plan). However, each method provides different demographic data for use in further analysis (Figure 5.4). See Table 5.4 for additional information regarding the terminology used in process charts.

Variables for some methods can be refined via analysis of the archaeological evidence. Depending on the size of the residential floor area and the resulting space per person, one or more of the family sizes used in the HUM can be removed from the final estimate.

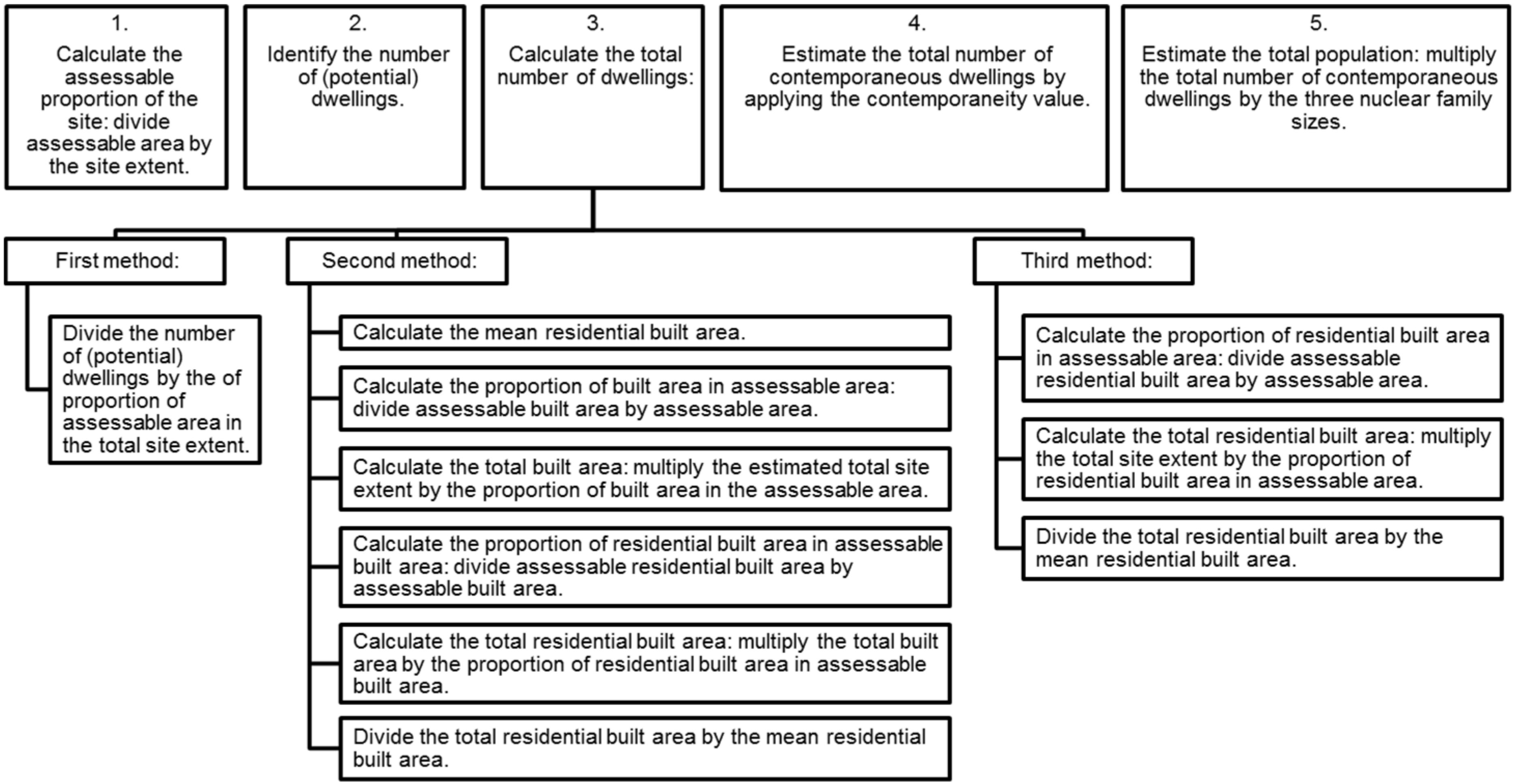


Figure 5.4. The housing unit method (HUM) process.

5.2.5 Residential area density coefficient method (RADC)

Residential area density coefficients (RADC) are a measure of the amount of residential area required per person. RADC estimates for settlements comparable to PPN central and southern Levantine villages vary significantly from around 1.86 m^2 to 10.4 m^2 per person (see Table 4.2). Variation is due to the type of dwelling and the constitution of the dwelling unit; environmental conditions relating to the need for shelter and the economic capacity for keeping warm in cooler temperatures; perceptions relating to crowding, privacy and personal space; and, perhaps predominantly, theoretical and methodological issues relating to the definition and measurement of residential area (see Section 4.1.2).

In this investigation, the RADC is based on residential floor area and relates to potential sleeping area only. The minimum RADC utilised in this investigation is sourced from Hemsley's (2008, p.131) research into the affordance of space within PPN dwellings, in which she estimated a maximum sleeping space requirement of 1.77 m^2 per person. This is marginally lower than Hayden *et al.*'s (1996) estimate for villages in the Arctic Circle (2.16 m^2). The mid-range RADC employed is 3.3 m^2 per person based on Hayden *et al.*'s (1996, p.159) range of 2.8 m^2 to 3.8 m^2 for Keatley Creek pit houses and Clarke's (1974) estimate of 3.33 m^2 for Southwest American pueblos. The maximum RADC employed is five m^2 per person based on Hill's (1970) estimate of 4.55 m^2 per person at the archaeological site of Broken K Pueblo in the American Southwest and Kramer's (1979) estimate of 4.82 m^2 living space per person based on ethnographic research in Shahabad, Iran.

The basic formula for deriving estimates via the RADC method is:

$$\text{Total population} = \frac{\text{total residential floor area}}{\text{RADC (residential floor area per person m}^2\text{)}}$$

Total residential floor area is calculated via three different methods. Each produces the same estimate, but again provides additional demographic data for further analysis (Figure 5.5).

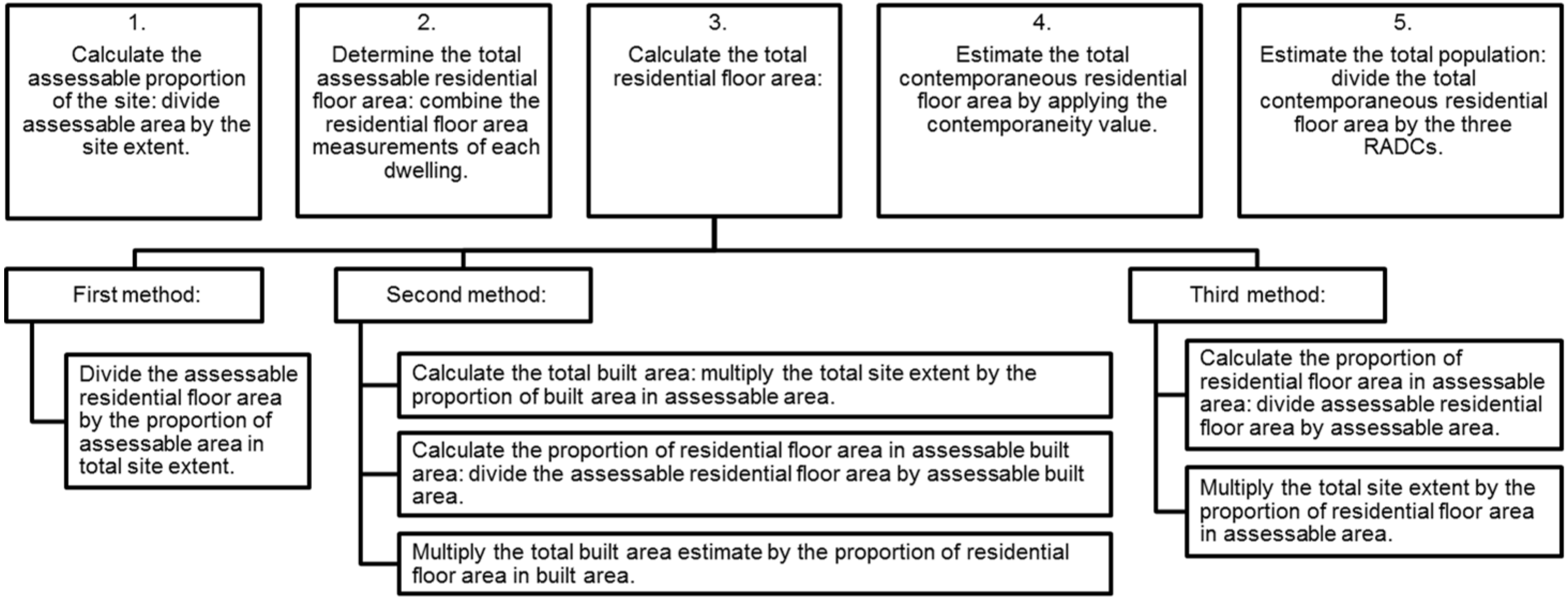


Figure 5.5. The residential area density coefficient (RADC) method process.

5.2.6 Storage provisions formulae (SPF)

A series of storage provisions formulae (SPF) were developed based on Hemsley's (2008) research into the affordance of space within dwellings at PPN sites (see Section 4.5). The formulae correlate available residential floor area (A) to the mid-point of the maximum numbers of 1.65 m and 1.83 m tall occupants lying in an extended position, factoring in access routes, hearths and activity zones, and three potential amounts of storage: none, moderate and high (Table 5.8).

Table 5.8. Storage provisions formulae (based on data from Hemsley 2008).

Annual personal storage within the residential floor area	Formula
None	P = 0.3944A - 0.375
Moderate (0.46 m^3 per person)	P = 0.2477A + 0.0339
Maximum (2 x 0.46 m^3 per person)	P = 0.1903A + 0.3976

In this investigation, the formulae are applied using residential floor area (i.e. potential sleeping area) as the A variable to determine maximum adult dwelling occupant numbers. The potential amount of storage (both permanent and ephemeral) within the residential floor area is derived from an assessment of the archaeological remains, predominant subsistence strategy and the general relationship between storage facilities and residential area per period. This evidence often enables one or more of the storage provisions formulae to be removed from the final estimate.

The SPF utilises the formulae to calculate total (adult) population (Method 1) and the number of people (i.e. adults) per dwelling (Method 2) from the total contemporaneous residential floor area, the mean residential floor area of complete dwellings and a total contemporaneous dwelling number estimate (Figure 5.6). The mean of Methods 1 and 2 are used to form the final population estimate range.

Of the four methods utilised to produce population estimates in this investigation, the SPF is considered the most beneficial and robust for several reasons. Firstly, this unique methodological approach is based almost exclusively on archaeological evidence and empirically derived values for adult human sleeping space. It does not incorporate assumptions regarding dwelling unit size or composition, or perceptions relating to space preference. All other methods assessed in this investigation are based on several assumptions that cannot be verified and employ ethnographically derived constants from settlements that often do not demonstrate a high degree of comparability to PPN villages.

Secondly, assessment of the archaeological evidence for storage within the residential area and a comparison of population and dwelling unit size estimates with estimates of available residential floor area enable the selection of the most appropriate formula/e for final estimate reconstruction. This not only reduces the final estimate range, but also highlights the most plausible amount of residential storage.

Thirdly, this is the only method which directly calculates dwelling unit size.

Finally, the consistent methodological application of set formulae improves the comparative capability of the results.

Due to the more empirically robust nature of the SPF method, SPF estimates are considered the most reliable (see Section 10.2.1). SPF estimates are, therefore, presented as the final estimates for comparative analysis in this investigation and are utilised as the population variable (P) within the allometric growth formulae.

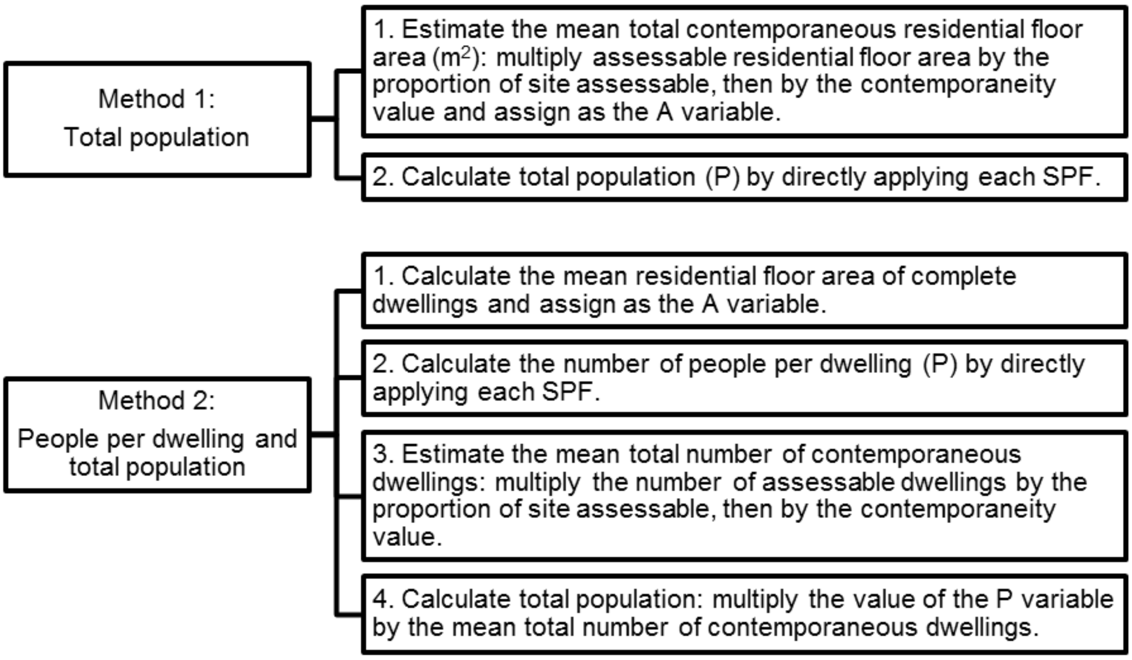


Figure 5.6. The storage provision formulae (SPF) process.

5.2.7 Allometric growth formulae (AGF)

Allometric growth formulae (AGF) correlate area (A) to population size (P) based on an initial growth index (*a*) and a scaling exponent (*b*), as follows:

$$A = a \times P^{b}$$

This investigation explores AGF developed specifically for archaeological sites by Naroll (1962) (AGF1) and Wiessner (1974) (AGF2) (see Section 4.1.4). The main aim is to derive a universal initial growth index, or set of indices for different settlement types, in order to estimate the population of any PPN village directly from estimated total site extent.

Naroll's (1962) formula is expressed as:

$$A = 21.7 \times P^{0.84195}$$

where A is the total built floor area and P is population size. The initial growth index (*a*) is 21.7 and the scaling exponent (*b*) is 0.84195. Two methods are explored (Figure 5.7). The first method applies the SPF population estimates for each site as the P variable to calculate the total built floor area and the amount of built floor area per person. The latter value is converted to residential floor area per person (RADC) based on the proportion of residential floor area in built floor area. Where comparability exists between these RADCs and those derived via the SPF population estimates, it is suggested that Naroll's formula may be suitable for estimating the population of these sites. The second method re-calculates the initial growth index based on the estimated total built floor area and the SPF population estimates. Where comparability exists between Naroll's original index (21.7) and the re-calculated indices, it is again suggested that Naroll's formula is suitable for estimating the population of these sites.

In Wiessner's (1974) formula, A is the total site extent, P is population size, the initial growth index (*a*) is variable and the scaling exponent (*b*) alters for different settlement types: two for open settlements ($b = 2$), one for villages ($b = 1$) and two-thirds for urban settlements ($b = 0.6667$). The initial growth index is calculated for each of the three settlement types based on the total site extent estimate and SPF population estimates (Figure 5.8). It is hypothesised that the scaling exponent for village settlements will produce relatively consistent initial growth indices for all sites assessed at the micro-level. In addition, the scaling exponent for open settlements is expected to produce comparable initial growth indices for PPN circular hut compounds; whilst the scaling exponent for urban settlements is expected to produce comparable indices for later PPN settlements containing agglomerated and multi-storey, rectilinear structures.

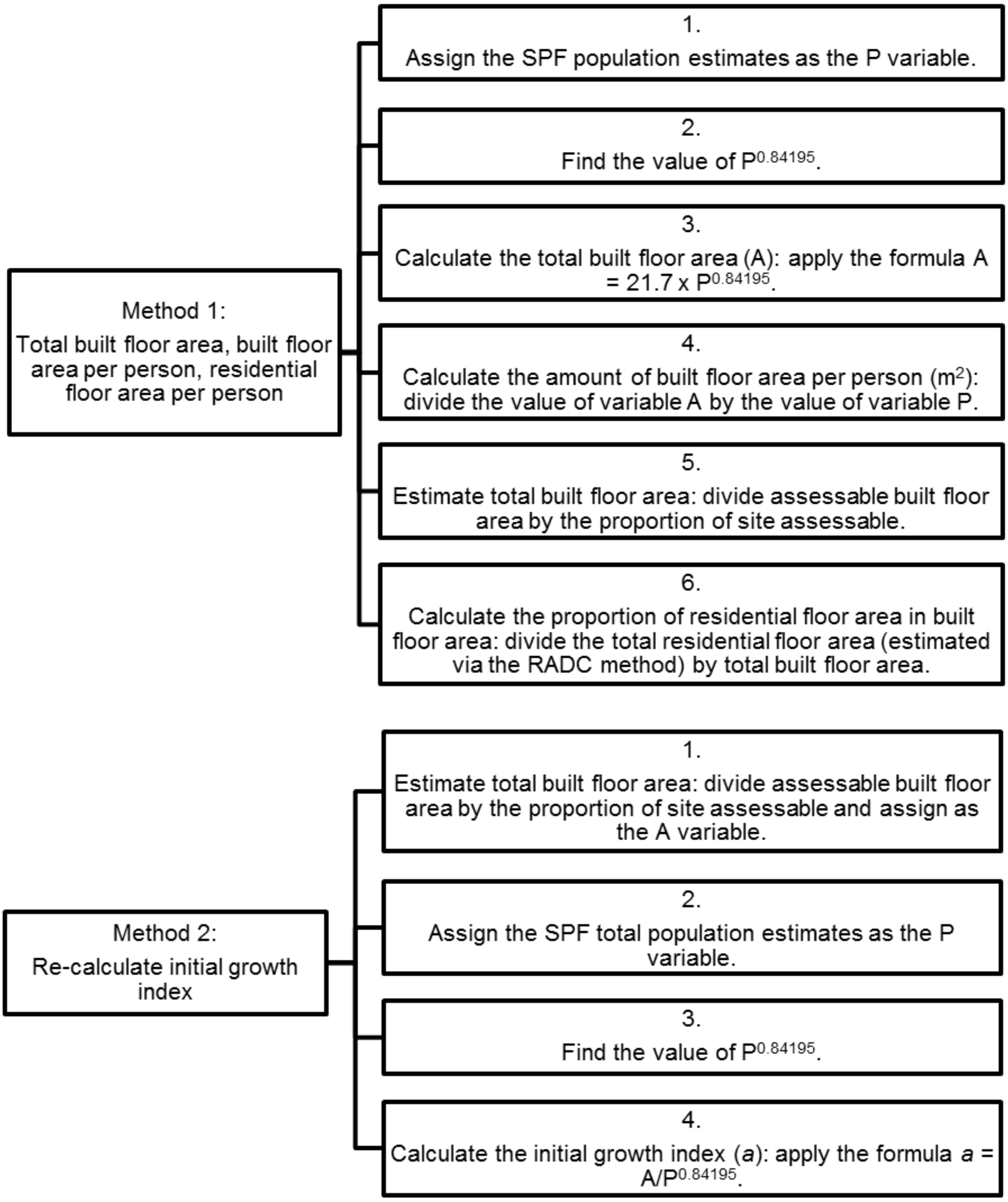


Figure 5.7. Naroll’s (1962) allometric growth formula (AGF1) process.

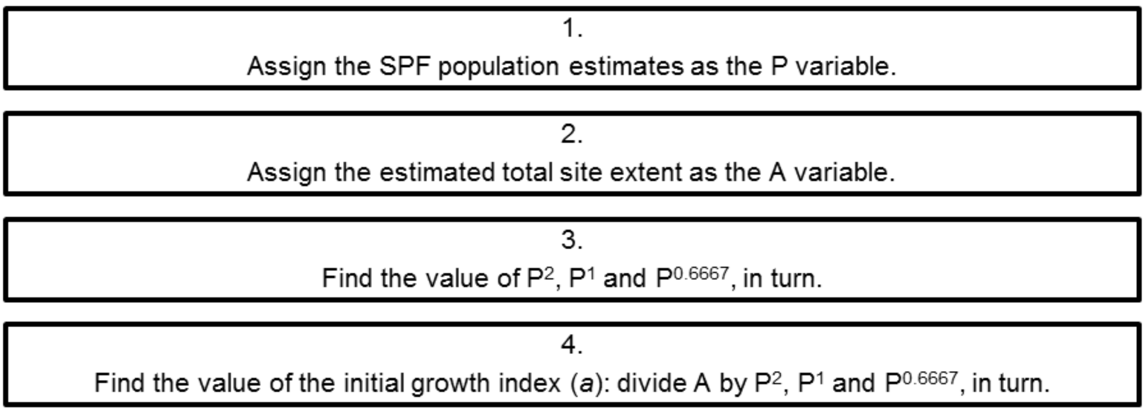


Figure 5.8. Wiessner’s (1974) allometric growth formula (AGF2) process.

5.2.8 Settlement population density coefficient method (SPDC)

Settlement population density coefficients (SPDC) are a measure of the number of people per hectare. The basic formula for deriving estimates via the SPDC method is:

Total population = total site extent (ha) x SPDC (people/ha)

Almost all existing population estimates for PPN central and southern Levantine villages are based on this method (see Section 4.3.1). These estimates generally utilise minimum and maximum values of 90 and 294 people per hectare based on ethnographic research in Iran (Watson 1978; Kramer 1982) and North Yemen (van Beek 1982). An average density of around 150 people per hectare is also commonly utilised based on the general density range of 100 to 200 people per hectare for modern Southwest Asian villages (Sumner 1979; Adams 1981; Kramer 1982; Wossinik 2009).

To assess the suitability of these density coefficients for PPN central and southern Levantine villages, two SPDC methods are explored (Figure 5.9). In the first method, minimum, average and maximum density values of 90, 150 and 294 people per hectare are applied to total site extent to estimate population; and in the second, density values are derived from HUM, RADC and SPF population estimates produced in this investigation and estimated total site extent.

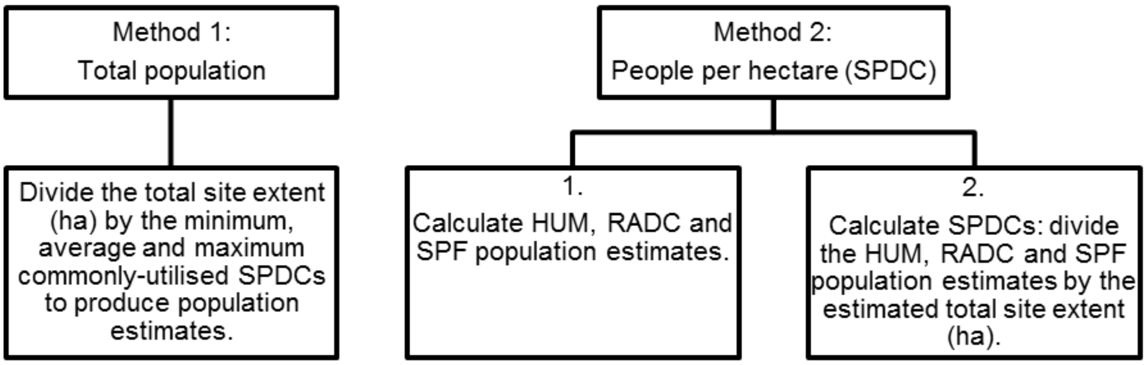


Figure 5.9. The settlement population density coefficient (SPDC) method process.

5.3 Systematic estimates

To systematically estimate the population of all sites in the PPN central and southern Levantine village database, information extrapolated from the results of micro-level analysis was used to develop a site type classification system (based on architectural form and site size) and universal and site type constants for all variables employed within the systematic methodologies (see Sections 8.1-8.3). Seven methodologies were employed to systematically estimate population parameters of each village based on an assigned site type, associated constants and an estimated total site extent (Table 5.9).

There are several issues with applying systematic methodologies. The foremost of these include problems with total site extent estimates (addressed in Section 5.1.2); the use of standardised constants; and the inability to classify some sites. The application of standard constants for variables (i.e. people per dwelling; residential floor area per person; people per hectare) is questionable as the further removed these constants are from the source of their development, the greater the potential for compounding errors. This is particularly the case where more than one type of constant is utilised within the same methodology (i.e. the residential built area proportions (RBAP) method; see Section 5.3.2). The combination of ranges for these constants can cause considerable estimate ranges, which are ineffectual for further demographic analysis.

An additional problem with the use of standardised constants is that these cannot reflect the real diversity that occurs within settlements. In this investigation, this diversity is accounted for to some degree by developing constants for different site types. However, not all sites conform exactly to a site type category. One of the major characteristics determining site type in this investigation is predominant architectural form (i.e. curvilinear or rectilinear) (see Section 8.2). For a limited number of sites, predominant architectural form could not be identified and, thus, these sites could not be classified (e.g. EPPNB Mishmar Ha'emeq; MPPNB Nahal Betzet I). Estimates for unclassified sites are based on universal constants, which can result in excessive estimate ranges.

Table 5.9. Systematic methodologies: outputs and data required.

Method	Estimates produced						Data required														
	Population size	People per dwelling	Total number of contemporaneous dwellings	Total contemporaneous residential built area (m^2)	Total contemporaneous residential floor area (m^2)	Total built floor area (m^2)	Site type	Total site extent	Contemporaneous dwellings per hectare	People per dwelling	Proportion of contemporaneous residential built area in assessable area	Mean residential built area of complete dwellings (m^2)	Proportion of contemporaneous residential floor area in assessable area	RADC (m^2 residential floor area per person)	Mean residential floor area of complete dwellings (m^2)	Probable amount of residential storage provisions	Mean total number of contemporaneous dwellings from RPDC/RBAP methods	SPDC (people per hectare)	Proportion of built floor area in assessable area	AGF1: re-calculated initial growth index	AGF2: village initial growth index
RPDC	✓		✓				✓	✓	✓	✓											
RBAP	✓		✓	✓			✓	✓		✓	✓	✓									
RFAP	✓				✓		✓	✓					✓	✓							
SPF	✓	✓			✓		✓	✓					✓		✓	✓	✓				
SPDC	✓						✓	✓										✓			
AGF1	✓					✓	✓	✓											✓	✓	
AGF2	✓						✓	✓													✓

5.3.1 Regional population density coefficient method (RPDC)

A regional population density coefficient (RPDC) is a measurement of the density of dwellings per unit of area (i.e. a hectare) (Wendt and Zimmermann 2009; Zimmermann *et al.* 2009). RPDCs are utilised to estimate total population based on the same premise as the micro-level housing unit method (HUM), where:

Total population = number of dwellings x number of people per dwelling

Universal and site type constants for the number of contemporaneous dwellings per hectare derived from micro-level analysis are applied to site extent estimates to calculate the total number of contemporaneous dwellings at each site. This is multiplied by universal and site type constants for the minimum, mean and maximum number of people per dwelling to produce population estimates for each site (Figure 5.10).

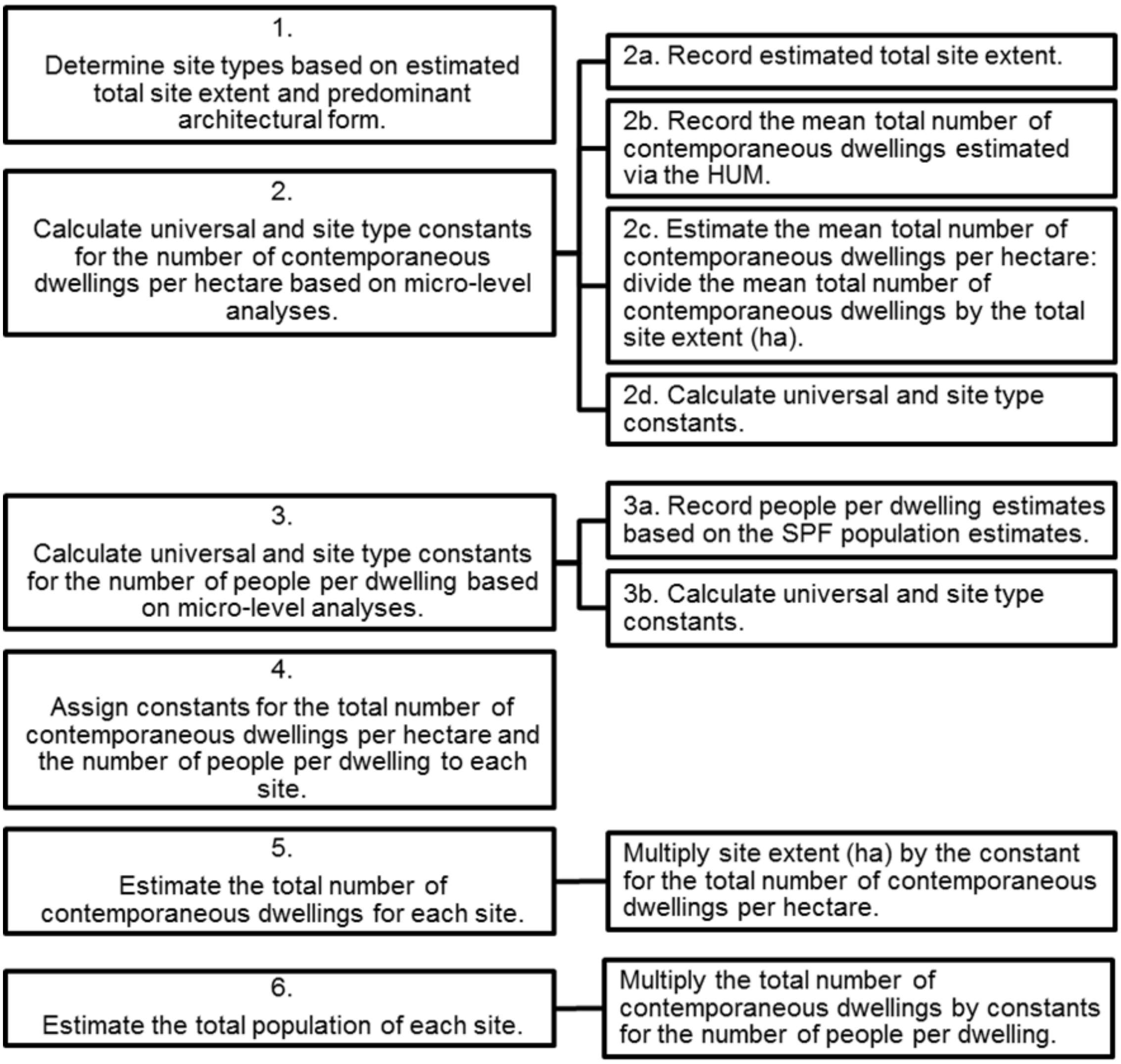


Figure 5.10. The regional population density coefficient (RPDC) method process.

5.3.2 Residential built area proportions method (RBAP)

The proportion of contemporaneous residential built area in site area (RBAP) is utilised to estimate total contemporaneous residential built area based on total site extent. This is divided by universal and site type constants for the mean residential built area of complete dwellings to calculate the total number of contemporaneous dwellings. This is multiplied by universal and site type constants for the number of people per dwelling to produce population estimates (Figure 5.11).

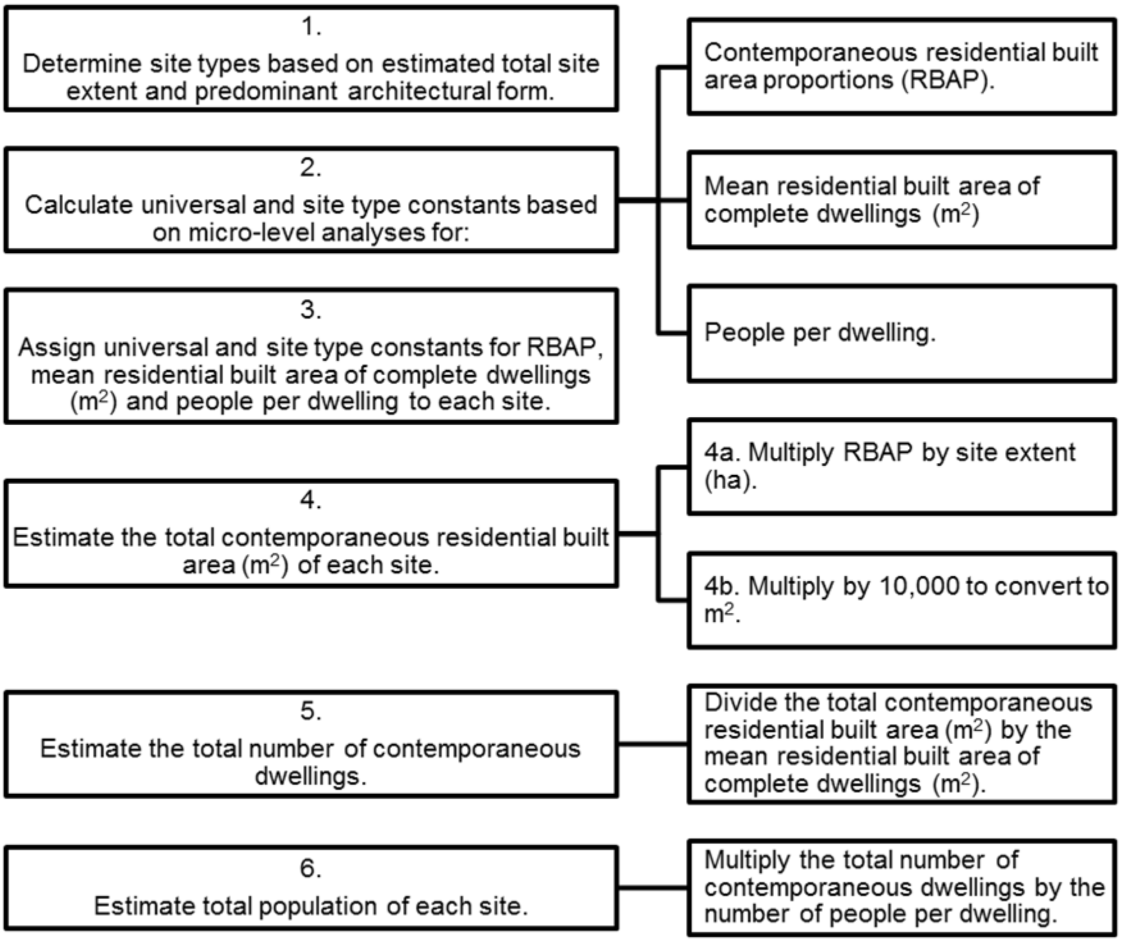


Figure 5.11. The residential built area proportions (RBAP) method process.

5.3.3 Residential floor area proportions method (RFAP)

The proportion of contemporaneous residential floor area in site area (RFAP) is utilised to estimate the total contemporaneous residential floor area based on total site extent. This is divided by universal and site type constants for residential floor area per person (m^2) (RADC) to produce population estimates (Figure 5.12).

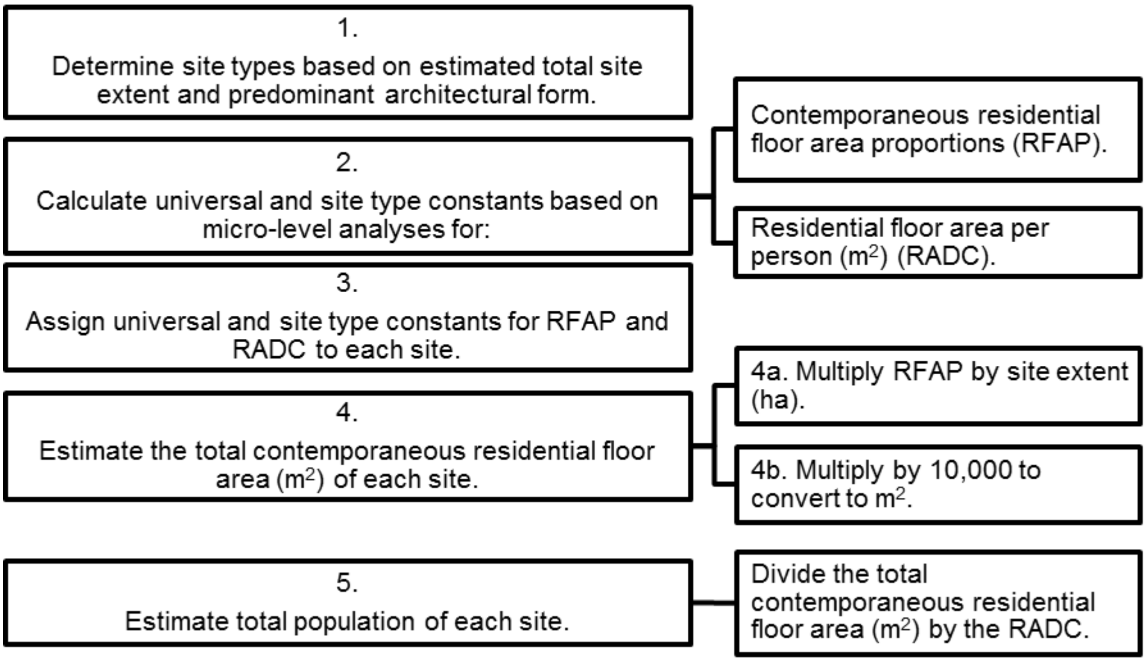


Figure 5.12. The residential floor area proportions (RFAP) method process.

5.3.4 Storage provisions formulae (SPF)

The storage provision formulae (SPF) derived from Hemsley's (2008) data are applied systematically based on the same method utilised in micro-level estimates (see Section 5.2.6). Two methods are explored: the first calculates population from total contemporaneous residential floor area, whilst the second calculates the number of people per dwelling from the mean residential floor area of complete dwellings and multiplies this by the total number of contemporaneous dwellings to produce population estimates (Figure 5.13). The potential amount of storage provisions per site type is derived from micro-level analysis. The mean of Methods 1 and 2 are used to form the final population estimate ranges.

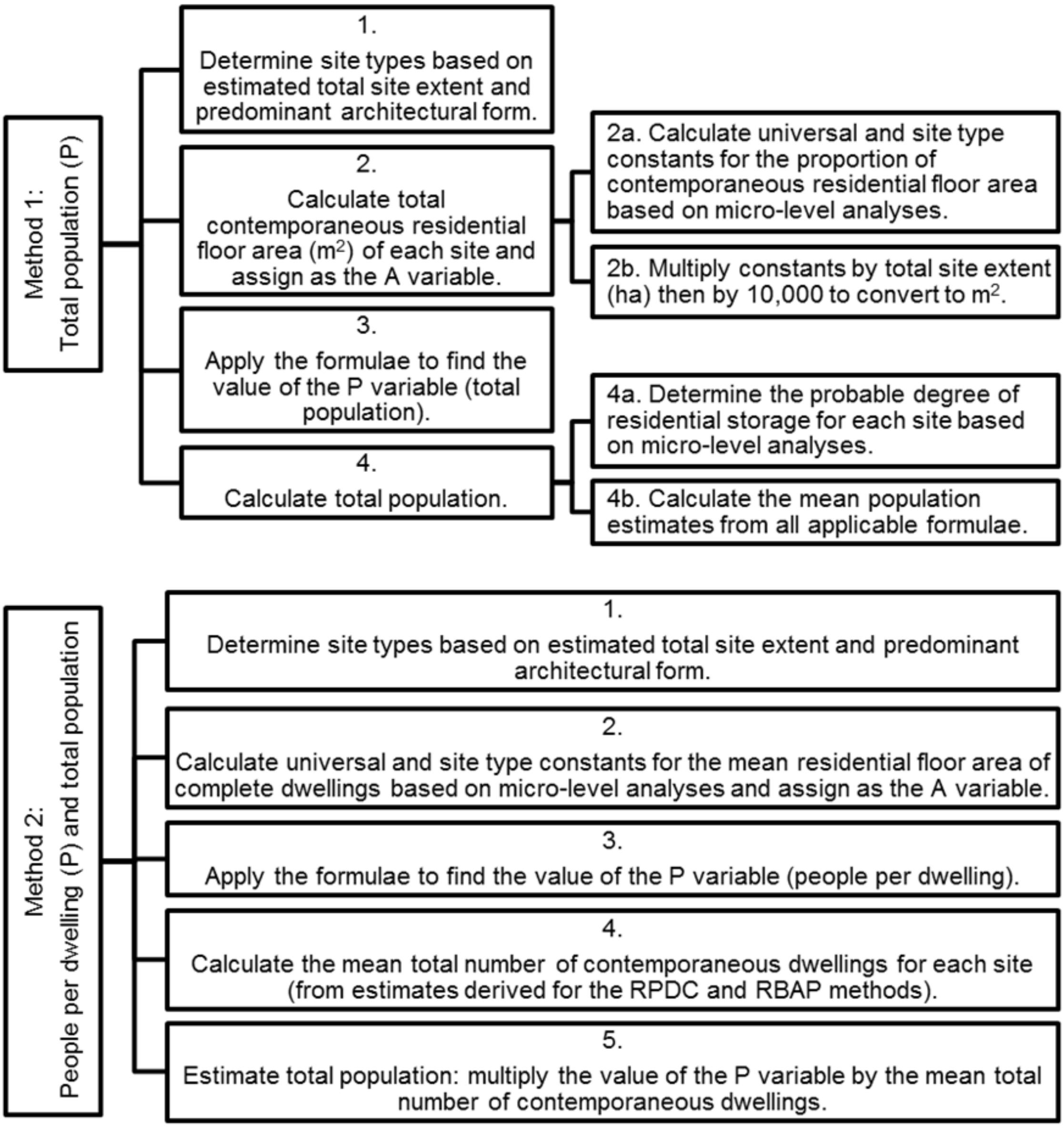


Figure 5.13. The storage provisions formulae (SPF) process for systematic estimates.

5.3.5 Settlement population density coefficient method (SPDC)

The settlement population density coefficient (SPDC) method is applied systematically to all sites based on the same method utilised in micro-level estimates. Universal and site type constants for the number of people per hectare are applied to total site extent to produce population estimates (Figure 5.14).

1.
Determine site types based on estimated total site extent and predominant architectural form.

2.
Calculate universal and site type settlement population density coefficients (SPDCs) (people per hectare) based on micro-level analyses.

3.
Estimate total population: multiply SPDCs by total site extent (ha).

Figure 5.14. The settlement population density coefficient (SPDC) method process for systematic estimates.

5.3.6 Allometric growth formulae (AGF)

Allometric growth formulae (AGF) are applied systematically to estimate population using the formula:

$$P = (A/a)^{1/b}$$

where P is population size, A is area, *a* is the initial growth index and *b* is the scaling exponent.

Naroll's (1962) re-calculated initial growth index (AGF1)

The AGF1 employs Naroll's (1962) scaling exponent (*b* = 0.84195) and constants for the re-calculated initial growth index (*a*) to calculate population size (P) from total built floor area (A). The AGF1 is expressed as:

$$P = (A/a)^{1/0.84195}$$

Total built floor area (A) is calculated via the application of universal and site type constants for the proportion of built floor area in site area to total site extent (Figure 5.15).

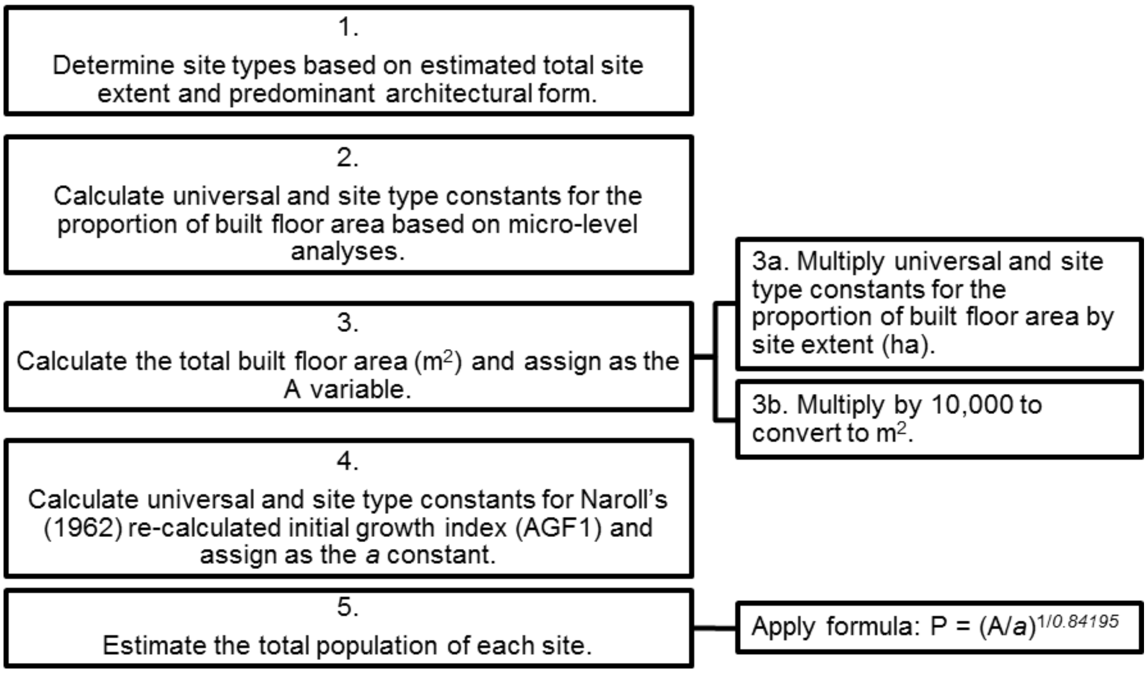


Figure 5.15. Naroll's (1962) allometric growth formula (AGF1) process for systematic estimates.

Wiessner's (1974) village formula (AGF2)

The AGF2 employs Wiessner's (1974) scaling exponent for village settlements (b = 1) and constants for the initial growth index (a) to calculate population from total site extent. The AGF2 is expressed as:

$$P = (A/a)^{1/1}$$

where P is population size, A is total site extent and a is the initial growth index (Figure 5.16). As Wiessner's (1974) scaling exponent for villages equals one, the formula can be more simply expressed as P = A/a.

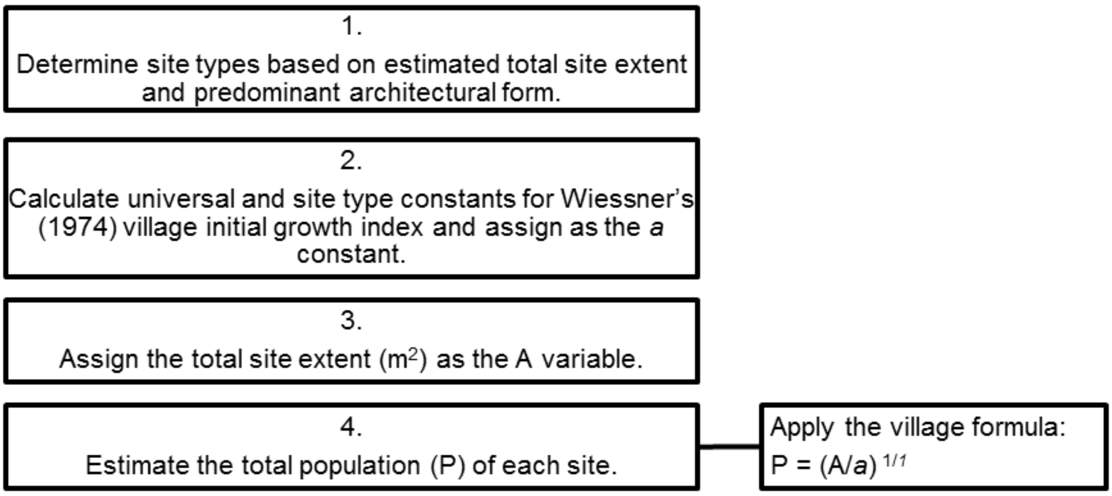


Figure 5.16. Wiessner's (1974) allometric growth formula (AGF2) process for systematic estimates.

5.4 Summary

This investigation aims to produce more empirically and statistically robust absolute estimates of PPN central and southern Levantine villages. Population estimates are commonly based on total site extent. In this investigation, published site extents were critically assessed to ensure that these were not overestimated and to assign site extents where these were not previously provided. Of the 106 villages and village phases in the site database, 15 demonstrate sufficient evidence for micro-level analysis. This chapter outlines the processes for several micro-level and systematic methodologies for estimating population parameters. The following chapter illustrates in detail the application of micro-level methodologies to the settlement at Beidha, southern Jordan.

6 Micro-Level Estimates – Part I: Beidha, Southern Jordan

This chapter presents the preliminary application of methodologies for estimating population parameters to the PPN village of Beidha, southern Jordan. Archaeological background is provided, including a description of features by subphase and major developments in subsistence, architecture, economy, ritual practices and community organisation. Radiocarbon dates are examined alongside the archaeological evidence to establish subphase length and building use-life estimates for reconstructing structural contemporaneity values. Results are presented for each subphase, followed by an overall analysis of methods and estimates. The process and results of each method are presented in detail for Subphase A1. Additional information for the remaining subphases and a database of results are provided in Appendices B.1 and B.2[1].

6.1 Site description

Beidha is a small MPPNB/LPPNB village situated in an alluvial valley bordered by steep sandstone cliffs to the north and the Wadi el-Ghurab to the south (Figure 6.1). The extensive and well-documented PPN occupation evidence provides an excellent opportunity for preliminary application of methodologies for estimating population parameters. Beidha demonstrates the full demographic transition from an incipient sedentary community reliant on hunter-gatherer subsistence practices, to a well-established sedentary society engaged in agro-pastoralist subsistence strategies.

Byrd (2005a) published an extensive volume on the architectural features excavated by Kirkbride (1966; 1985), re-examining the evidence to refine the stratigraphic sequence. Three main phases were identified (A, B and C) (Byrd 2005a, p.15). Phases A and C were divided into two subphases (A1 and A2; C1 and C2). Evidence exists for earlier and later Phase B remains, assessed as Subphases B1 and B2 in this investigation.

Byrd (2005a, p.131) proposes a total site extent of between 0.15 ha and 0.35 ha. Individual subphase site extents are suggested in this investigation based on the potential degree of village expansion as indicated by topographical location, the number and distribution of structures per subphase and information relating to construction timing, longevity and abandonment (Byrd 2005a). A site extent of 0.1 ha is suggested for Subphase A1; 0.2 ha for Subphases A2 and B2; and 0.3 ha for Subphase C2.

[1] Article published in *Levant* based on Chapter 6 (Appendix B.3).

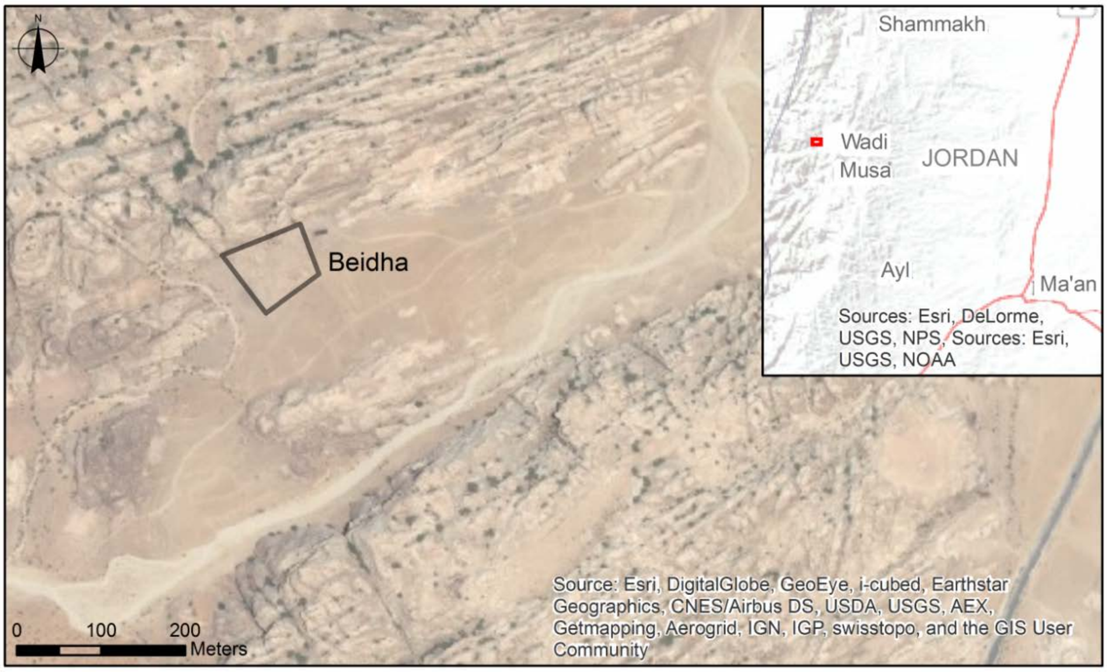


Figure 6.1. Location of Beidha excavation area, southern Jordan.

6.1.1 Phase A (Subphases A1 and A2)

Phase A occupation has been dated to the early MPPNB, with a suggested start date of sometime after c. 7,000 BC (Byrd 2005a, p.26). Subphase A1 directly overlies ephemeral EPPNB deposits. Around 130 m^2 of Subphase A1 occupation was excavated, providing the earliest evidence for permanent structures at this site (Figure 6.2). The architecture comprises semi-subterranean, earthen and masonry structures, with lightweight, organic roofing. Byrd (2005a, pp.33-36) identifies four large curvilinear, post-socketed structures as dwellings (Buildings 18, 41, 48 and 49), and two smaller, sub-square structures as annexes (Buildings 17 and 50). At some point, the function of Building 41 appears to have altered from that of a dwelling to a burial area. The open area north of Building 41 appears to have been utilised as communal space. Evidence suggests that the village wall and steps were constructed during this subphase, reducing erosion of the alluvial terrace upon which the village was built (Byrd 2005a, p.31).

Around 300 m^2 of Subphase A2 occupation was excavated, revealing nine curvilinear structures and the eroded remains of a further two to the south of Building 21 and east of Building 74. Stratigraphic evidence suggests that seven buildings were constructed in short succession (Buildings 21, 38, 51, 52, 56, 74 and 83) (Byrd 2005a, p.18). Architecture generally comprised post-socketed, earthen and masonry structures, with beam and reed roofing (Byrd 2005a).

Byrd (2005a) identifies six Subphase A2 dwellings (Buildings 33, 51, 55, 56, 74 and 83), whilst a further three (Buildings 38, 53 and 54) have been assigned as potential dwellings in this investigation based on comparable architectural form and interior features. A large, semi-subterranean structure (Building 37) at the centre of the excavated area was identified as non-residential. This structure was associated with open communal areas to its north and east (Byrd 2005a).

Buildings (29, 53, 54 and 55) exposed in the northern section were not assigned to a subphase by Byrd (2005a). However, Byrd (2005a, p.19) considers it “unlikely” that Buildings 54 and 55 comprise part of the initial Neolithic occupation, highlighting the fact that the foundations of Buildings 29 and 53 cut into earlier plastered surfaces. These buildings and remnants of other buildings eroding out of the slope to the west were all destroyed by burning, which may have been simultaneous with the major conflagration event that terminated Subphase A2. Based on this evidence, these buildings are tentatively assigned to Subphase A2 in this investigation.

6.1.2 Phase B (Subphase B2)

Around 600 m^2 of Phase B occupation was excavated, exposing at least 18 predominantly curvilinear, single-roomed, semi-subterranean, earthen and masonry structures, with mudbrick upper walls and plastered floors (Figure 6.3). The majority were accessed via stone steps. Several earlier Phase B structures (Buildings 25, 26, 34, 40, 43 and 60) were superimposed by or cut into by later Phase B structures (Buildings 24, 25, 35, 36, 42, 47 and 61). A considerable amount of the later Phase B occupation was destroyed by Phase C construction (Byrd 2005a, p.19).

Byrd (2005a, pp.44-47 and 115) identified seven dwellings (Buildings 25, 34, 35, 40, 47, 60 and 61). Buildings 25 and 40 are sub-square with a pronounced entrance and limited internal features. Buildings 34, 35, 47 and 60 are ovoid with simple entrances. Building 60 had ceiling plaster, a quern, sandstone slabs and a possible raised rim hearth associated with a stone platform. Building 61 is a unique rectilinear building with a series of benches and platforms associated with a quern and stone bowls. Beyond this structure lies a quern and sandstone slabs set into a plaster surface.

Buildings 24 and 44 have been assigned as potential dwellings in this investigation based on morphological similarity to Buildings 40 and 60, and other features including plastered ceilings, walls and floors; raised-rim hearths associated with querns, stone slabs and stone bowls; stone platforms; and occupation debris. Similarly, despite the limited exposure, Buildings 36 and 82 were assigned as potential dwellings based on the presence of rimmed hearths and plastered floors. Of the 11 dwellings identified, eight (Buildings 25, 34, 36, 44, 47, 60, 61 and 82) were assigned to Subphase B2 based on the stratigraphic sequence proposed by Byrd (2005a).

Buildings 26, 31, 42 and 81 have been interpreted as non-residential structures probably relating to ritual activities, based on their comparatively large size and large interior hearths (Byrd 2005a, p.115). Buildings 15 and 43 were minimally exposed, revealing insufficient information to interpret building function. Building 15 is possibly an extension of Building 44. However, as the relationship remains unclear, Building 15 is assigned as non-residential area in this investigation given the limited interior floor area. A large outdoor activity area lies to the west of Buildings 25 and 60, containing plastered surfaces, large hearths and stone slabs. A stone-lined pit just north of Building 81 appears to have continued in use during Phase C (Byrd 2005a, p.51).

6.1.3 Phase C (Subphase C2)

Phase C occupation dates to the late MPPNB/LPPNB (although a PPNC date has been suggested by Rollefson (1998b)). Around 960 m^2 of Phase C occupation was excavated, revealing at least 25 buildings. Of these, nine were considered part of Subphase C1 construction; three as part of Subphase C2 construction; and the remainder non-subphased (Byrd 2005a). Several Subphase C1 buildings (n = 5) and two earlier Subphase C2 buildings (16 and 20) were superimposed by or destroyed in the construction of later Phase C structures. The remaining four Subphase C1 structures, as well as all non-subphased structures, were positioned alongside and interconnected with Subphase C2 structures, suggesting simultaneous use (Henry *et al.* 2003; Byrd 2005a). As such, 19 buildings are assessed as representing Subphase C2 occupation in this investigation (Figure 6.3). Subphase C2 is assessed as an LPPNB site.

Excavations exposed 14 masonry, corridor buildings or ‘pier houses’ (Byrd and Banning 1988, p.65) (Buildings 1-5, 10-14, 19 and 71-73), with semi-subterranean basements containing sets of small rooms separated by similarly sized piers. A further two partial structures to the west of Buildings 14 and 19 display sufficient morphological similarities for interpretation as potential dwellings.

Byrd (2005a, p.85) interpreted all dwellings as two-storey. Several buildings (2-5, 14, 19 and 73) retained evidence for an upper storey comparable in size to the lower storey, containing plastered floors and plastered, sandstone-slab walls. Byrd (2002, p.80) states that “cooking and eating, entertaining and sleeping presumably occurred primarily in the upper stories, based on the presence of hearths and a more open plan”. Building 14 demonstrated the best preserved upper storey evidence including a raised rim hearth with red paint and associated floor slabs (Byrd 2005a, p.65). Its lower storey contained numerous pestles, grinders, polishers and bone tools described as representing the workshop of a bone tool or bead specialist (Kirkbride 1966, p.25).

Several corridor buildings contained burials (Buildings 2-3, 5 and 12-13). At least one upper storey contained a storage bin (Building 73), whilst numerous dwellings (Buildings 2-4, 12, 19 and 71-72) contained blocked basement compartments which may have formed the base of similar storage facilities. Building 11 was either abandoned or underwent a functional change from a residential to non-residential structure with the construction of Building 13 and is, thus, not assessed as a dwelling in this analysis.

Three structures were identified as non-domestic. These include a very large, rectangular, two-roomed building (Building 8); an irregular structure formed of a series of compartments interpreted as a roofed storage facility (Building 75) (Byrd 2005a, pp.69-70); and an additional wall further enclosing this facility (Building 76). A courtyard area with large hearths and other features similar to those of the courtyard areas in Phases A and B was located to the east and north of Building 8.

6.1.4 Societal conditions, processes and developments

Subsistence

Subsistence practices at Beidha reflect the full transition from hunter-gatherer (Phase A) to agro-pastoralist (Phase C) strategies. Phase A residents hunted wild animals, including goat and gazelle (Kirkbride 1966; Perkins 1966), and foraged for plant foods, such as nuts, acorns and wild oats (Kirkbride 1985). Outdoor courtyard areas were utilised for a range of domestic activities suggestive of a communal subsistence and a predominantly egalitarian ethos. Foraging activities continued during later phases alongside agricultural practices involving domesticated plants (i.e. barley and emmer), which emerged during Phase B and intensified during Phase C (Colledge 2001). Outdoor areas continued to be used for communal cooking activities throughout Phases B and C. Wild goats may have been culturally controlled during Phase B and possibly locally domesticated during Phase C (Kirkbride 1966; Perkins 1966; Mithen 2003). Phase C demonstrates a considerable array of processing tools and substantial space allocation for storage, processing and preparation of food resources within dwellings, indicating the potential economic independence of dwelling units (Wright 2000; Byrd 2005a).

Architecture

During Phase A, thick-walled, curvilinear, earthen and masonry structures were built in primary dwelling clusters followed by secondary addition of abutting structures (Byrd 2005a). Architecture and layout is comparable to other PPN settlements at Dhra' (Kuijt and Mahasneh 1998), Shkārat Msaied (Kinzel *et al.* 2011), Nahal Issaron (Carmi *et al.* 1994), Abu Salem (Gopher and Goring-Morris 1998) and sites within the Azraq Basin (i.e. Wadi Jilat 7, 25, 26 and 32, and Azraq 31) (Garrard *et al.* 1994). Towards the end of Phase A, at least one large, communal building was constructed in the central area.

In Phase B, access to dwellings became more formalised and restricted, and interior space became more structured. There is increased distinction between residential and non-residential space, with multiple large, structures appearing to be in simultaneous use. Towards the end of Phase B, rectilinear architectural forms emerge.

During Phase C, non-residential architecture became highly distinctive, with a very large, rectangular, non-domestic structure and associated circular, potential storage facility dominating the central area. Numerous rectilinear, two-storey structures were built. These are interpreted as pier houses, each containing storage facilities and workshop areas on the ground floor and residential area on the upper floor (Byrd 2005a). These structures have been compared to those at Jericho (Kenyon 1981), 'Ain Ghazal (Rollefson *et al.* 1992), Beisamoun (Bocquentin *et al.* 2011) and Yiftah'el (Khalaily *et al.* 2008).

Economy

During Phase A, hunter-gatherer traditions persisted, with non-compartmentalised activities performed in undifferentiated residential spaces and little distinction between public and private space (Byrd 1994, p.649). Increased privacy and restricted access to residential space, and greater distinction between public and private domains during Phase B may reflect the emerging institutionalisation of the household or dwelling unit. By Phase C, architectural developments, including increased residential space, greater compartmentalisation within dwellings and more restricted access to buildings are considered to reflect well-established, potentially autonomous, household economic units. (Byrd 2005a, pp.121-122). There is evidence to suggest that these household units managed domesticated livestock, intensively produced and prepared food resources, and engaged in household-based specialist activities, such as bone tool and bead production (Kirkbride 1966; Byrd 2005a, pp.121-122 and 128). Byrd (2005a, p.121) suggests that dwelling units comprised nuclear families in all phases. This assumption was based on (1) the identification of structures as dwellings by the presence of hearths, bins, storage units and other domestic artefacts; and (2) correlations in the house size and floor area of these structures with those identified in ethnographic contexts, where nuclear families formed the predominant dwelling unit. Rollefson and Kafafi (2013, pp.11-13) propose that large, compartmentalised dwellings, such as those that existed during Phase C, may have accommodated large nuclear or extended family units.

Ritual and community organisation

Ritual activities are present in all phases, with numerous burials uncovered in Subphase A1 Building 41, which was interpreted as a possible mortuary structure towards the end of its use-life (Byrd 2005a). Subphase A2 provides increasing evidence for designated non-residential space including a large, centrally-located, curvilinear building (Building 37) interpreted as representing ritual, communal or decision-making activities. Several non-residential structures appear to be in simultaneous use in Phase B, suggesting increasing formalisation of ritual and communal activities. During Phase C, a very large, centrally-located, unique, non-residential structure associated with potentially centrally-managed storage was interpreted as representing a form of corporate management, reflecting increasing social complexity and possible hierarchical differentiation (Byrd 2005a, p.129). Potential social differentiation may also be evidenced by increasing variability in residential architecture (Wiessner 1982; Saidel 1993; Rollefson and Kafafi 2013) and by items of personal adornment (i.e. beads, pendants, necklaces), which have been interpreted as mechanisms for individual or group identity (Wright and Garrard 2003; Edwards 2007).

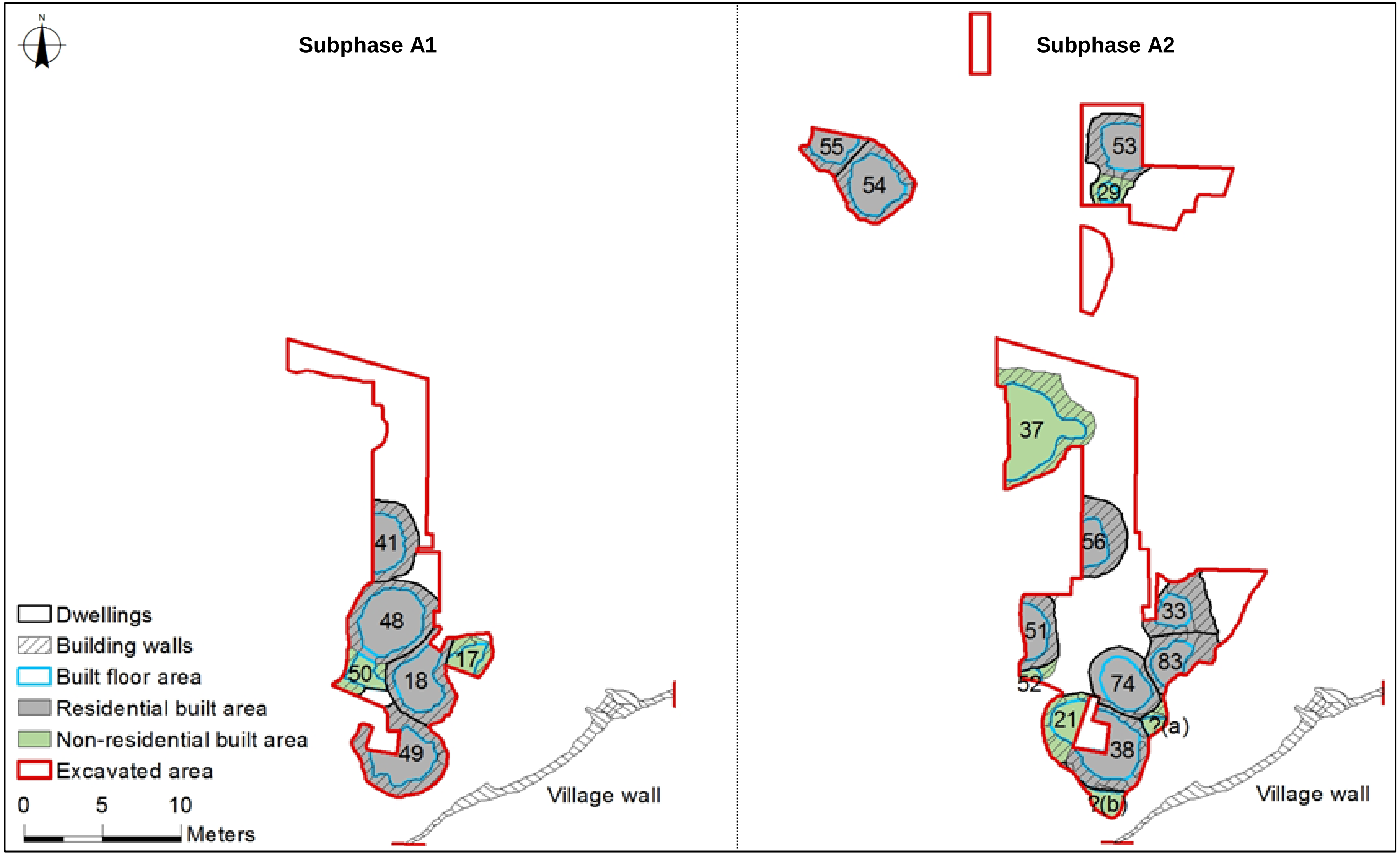


Figure 6.2. Site plans of Beidha Subphases A1 and A2 (transcribed from Byrd 2005a, pp.180 and 183).

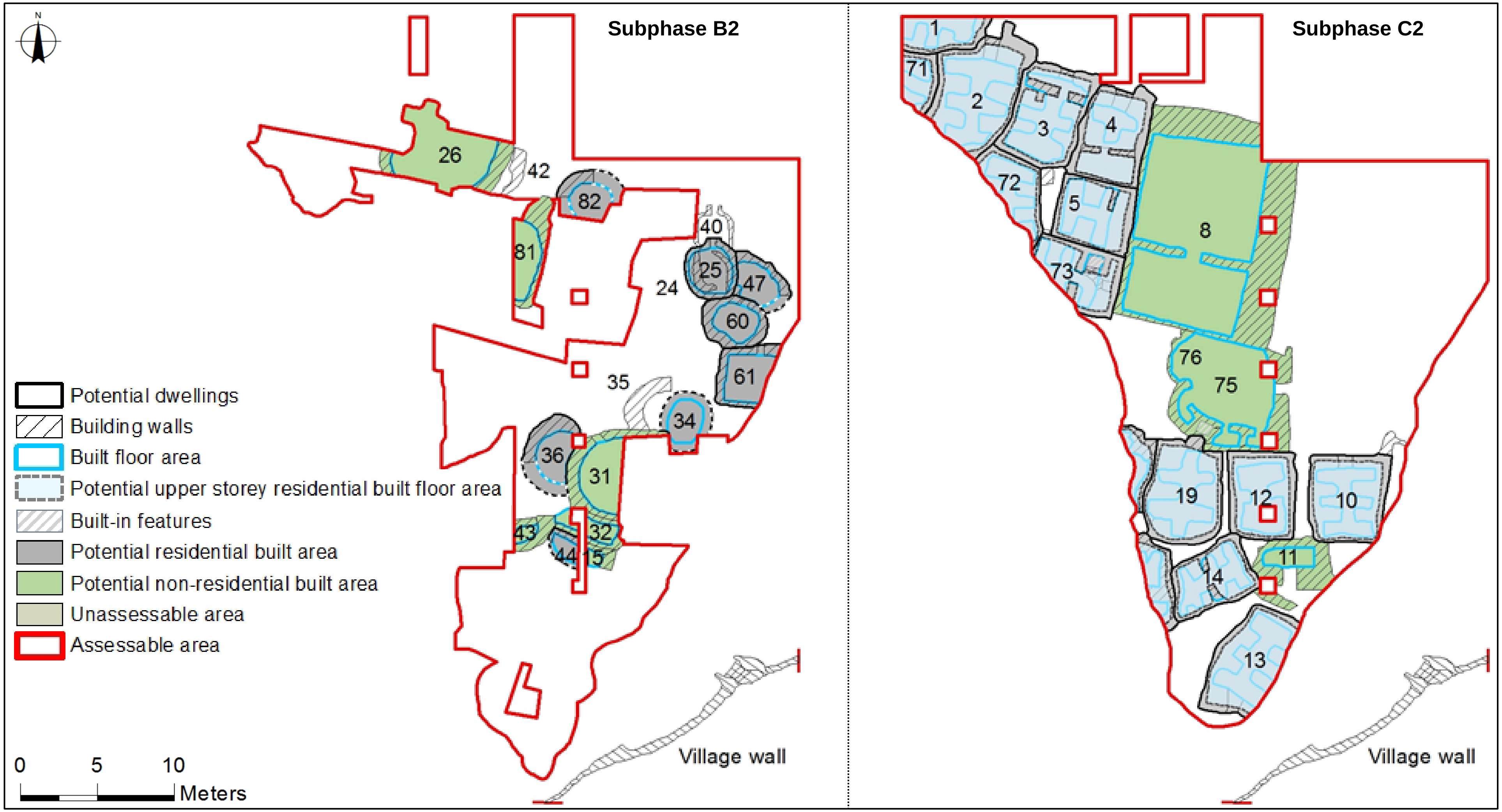


Figure 6.3. Site plans of Beidha Subphases B2 and C2 (transcribed from Byrd 2005a, pp.186, 192 and 195).

6.1.5 Estimating structural contemporaneity

Adjustments to reflect the potential number of contemporaneous structures are essential when reconstructing population sizes. The method employed in this investigation calculates structural contemporaneity based on span estimates for building use-life and phase length (see Section 5.2.3). Precise span estimates were produced via (1) analysis of chronological information relating to the stratigraphic sequence at Beidha (Byrd 2005a); (2) estimates of building use-life of comparable structures derived from archaeological, ethnographic and experimental research; and (3) Bayesian chronological modelling of radiocarbon dates.

Prior chronological information

An occupation span of around 600 years is generally accepted for the PPN occupation at Beidha (Gebel 1987, p.346; Rollefson 1989b, p.169). Byrd (2005a, pp.26-27) analysed the radiocarbon dates and archaeological evidence to establish specific settlement and abandonment dates. Byrd (2005a, p.7) suggested that occupation may have spanned as much as 500 years from sometime after c. 7,000 BC, during the MPPNB, extending into the LPPNB beyond the latest reliable radiocarbon date of 6,596 ± 100 BC. It has been hypothesised that the inhabitants of the latest phase at Beidha migrated to Ba'ja during the LPPNB (Gebel 2003, p.18).

Byrd (2005a) attempted to refine phase boundaries by analysing radiocarbon dates from short-lived material. Byrd (2005a, p.27) proposed that Phase A began around 7,000 BC and probably ended around 6,700 BC. Unfortunately, due to several divergent dates, interpreted as the result of considerable disturbance processes, Byrd (2005a, p.27) was unable to establish boundary dates for Phases B and C. Byrd (2005a) suggests a span of 150 to 250 years each for these phases in order to place the final subphase (C2) in the LPPNB. These phase lengths equate to an occupation span of between 600 and 800 years. Byrd does not propose lengths for each subphase. However, given the proposed phase lengths and the lack of evidence for abandonment between phases and subphases (Byrd 2005a, p.12), a potential span of around 150 years each for Subphases A1 and A2, and around 100 years for each subphase within Phases B and C is suggested in this investigation based on Byrd's research.

Byrd (2005a) does not attempt to produce precise estimates of building use-life. However, based on the degree of remodelling and maintenance, and evidence for structural superpositioning and juxtapositioning, Byrd indicates relative longevity of structures per subphase, although his comments are rather vague. Subphase A1 structures are suggested to have spanned a “considerable period”, with Subphase A2 structures occupied for a “reasonable duration” (Byrd 2005a, pp.77-78). Variable spans are suggested for Phase B structures. He suggests that structures in the central cluster may have been occupied for a “considerable period”, whilst those in the northeastern corner may have been occupied for “relatively short periods” (Byrd 2005a, p.84). Byrd (2005a, p.94) suggests that Phase C dwellings had a “considerable duration of habitation”, which may have been relatively uniform across the site.

Byrd’s (2005a) detailed description of the architectural features and maintenance evidence enables reconstruction of building use-life estimates based on archaeological, ethnographic and experimental research of comparable structures (Table 6.1). Phase A and B architecture includes freestanding and interconnected, curvilinear structures with organic roofing and walls of earthen and masonry materials; whilst Phase C architecture includes agglomerated, rectilinear and often two-storey, predominantly masonry structures (Byrd 2005a, p.28). The majority of structures demonstrate a moderate to considerable amount of maintenance and remodelling, indicating deliberate attempts to extend the building use-life. A summary of occupation span, phase length and building use-life estimates based on Byrd’s (2005a) analysis and ethnographic, archaeological and experimental data is provided in Table 6.2.

Table 6.1. Beidha PPN building information (Byrd 2005a) and suggested use-life based on archaeological, ethnographic and experimental research of comparable structures.

Building/	Phase	Predominant construction material*	Degree of maintenance	Use-life (years)
18	A1	Earthen/masonry: *Wooden posts and stone cobble/ block walls; large central post supporting beam, clay, read and large stone slab superstructure*	Considerable: *Plastered walls; two floor levels with intervening fill deposits; considerable remodelling: blocked entrances, addition of annexes*	55-75
48	A1	Earthen/masonry: *Similar to Building 18*	Considerable: *Plastered walls and floor; Building 50 added as annex (modified several times)*	55-75
54	A2	Earthen/masonry: *Similar to Building 18*	Moderate-considerable: *Plastered walls, floor and ceiling; multiple plastering episodes; possible earlier floor layer; remodelling: blocked entrance/s*	35-75
74	A2	Earthen/masonry: *Similar to Building 18*	Moderate: *Plastered floor*	35-55
26	B2	Earthen/masonry: *Similar to Building 18 plus mudbrick upper walls*	Moderate: *Plastered walls, floor and ceiling; remodelling episode*	35-55
8	C2	Masonry: *Stone block/slab/rubble fill walls; wooden posts for additional support of heavy superstructure*	Considerable: *Plastered floor; at least four major re-modelling and re-plastering episodes*	75-100

* Earthen: Cameron 1990; Reynolds 1995; Diehl 2001; Ortman *et al.* 2007; Arnoldussen 2008; Kuijt and Finlayson 2009; Varien 2012. Masonry: Ahlstrom 1985; Rollefson and Köhler-Rollefson 1989; Hodder and Cessford 2004; Cessford 2005; Matthews 2005.

Table 6.2. Beidha PPN occupation span, subphase length and building use-life estimates based on Byrd 2005a and archaeological, ethnographic and experimental research.

	Phase/ Subphase: Building	**Byrd 2005a**		**Archaeological, ethnographic, experimental research**	
		Years	*Start date*[a]	*Construction and maintenance*[b]	*Use-life (years)*
Occupation span		500-800	6990±160 BC 8470-7600 cal BC		
Phase length	A	300			
	B	150-250			
	C	150-250			
Building use-life	A1: 18	Considerable		E/M, C	55-75
	A1: 48	Considerable		E/M, C	55-75
	A2: 54	Reasonable		E/M, Mod-C	35-75
	A2: 74	Reasonable		E/M, Mod	35-55
	B2: 26	-		E/M, Mod	35-55
	C2: 8	Considerable		M, C	75-100

[a] Start date: earliest radiocarbon date after 7,000 BC as suggested by Byrd 2005a; converted to cal BC in OxCal v.4.2.4 (Bronk Ramsey 2009).
[b] Construction - E: Earthen, M: Masonry; Maintenance - Mod: Moderate, C: Considerable.

Bayesian chronological modelling

Bayesian chronological modelling of radiocarbon dates was conducted to determine more precise start, transition and end dates for the various phases, subphases and structures at Beidha. Of the 23 radiocarbon dates associated with the PPN occupation deposits at Beidha, four have insufficient contextual information for inclusion in this analysis: Beta235216, AA13038, AA1461 and AA13037 (Table 6.3; Figure 6.4). The remaining 19 dates were statistically assessed to determine potential outliers. A Chi-squared test (χ^2) was conducted on the combined set of 19 radiocarbon dates ordered by subphase in descending chronological order of the earliest calibrated date ranges (Ward and Wilson 1978). The χ^2 result produced a ‘T’ value higher than the threshold based on the 5% confidence limit (given in brackets), indicating that at least one date does not conform to the stratigraphic constraints (Table 6.4).

Divergent dates were identified via Bayesian chronological modelling of the lower and upper occupation boundaries (‘start’ and ‘end’ dates). Convergence values indicated that all models were stable (C > 95%). Model index agreement values indicated five statistical outliers (all producing A ≤ 60%; AA14109, GrN5063, P1379, P1380 and GrN5062) (Table 6.5; Figure 6.5). Removal of the five potential outliers resulted in acceptable agreement index values (A ≥ 60%) in a subsequent run of the model (Figure 6.6) with χ^2 testing confirming that the refined dataset constituted a stratigraphically coherent group (Table 6.4). Following an assessment of the source material and the prior chronological information, the five outliers were deemed to represent residual or intrusive samples and were excluded from further analysis.

Table 6.3. Contextual information for Beidha PPN radiocarbon dates (*n* = 23) and justification for exclusion from analysis. Dates in descending chronological order of the earliest 95% probability distribution of radiocarbon dates (cal BC). Dates highlighted in grey are excluded.

Lab reference	Context		Material*	Radiocarbon date		Justification for exclusion
	Subphase: Location			*BP*	*Cal BC range (95%)*	
P1380	A2	Building 74: central post	CH: Pistacia	9128 ± 103	8640-7990	Poor agreement; considerably earlier than other PPN dates despite being from Subphase A2; one of three dates (including GrN5136 and K1083) derived from the same object - considerably earlier than the other two dates; potential old wood effect: potential timber re-use or tree potentially felled (or wood collected) years before use.
K1086	A1	Building 18: possible roof beam	CH: Quercus	8940 ± 160	8470-7600	
beta 235216		3.35 m; Neolithic layer right above sterile sand	CH	9110 ± 50	8460-8240	Insufficient contextual information
BM111	B2	Building 26: beam roof fall directly above floor	CH: ?	8790 ± 200	8430-7490	
AA1461		-	CH	8390 ± 390	8430-6470	Insufficient contextual information
GrN5062	C2	Building 8: possible wooden lid of stone-lined pit	CH: Juniper	9030 ± 50	8320-7990	Poor agreement; one of the earlier PPN dates despite being from Subphase C2 (last PPN phase); unclear nature of material (possible lid); potential old wood effect due to long-living species, potential timber re-use or tree potentially felled (or wood collected) years before use.
P1382	C2	Building 8: from near top of stone-lined pit	CH: ?	8892 ± 115	8290-7670	Below agreement threshold (A < 60%) in subphased sequence model (A = 29.5%); date retained as one of only two potentially suitable dates for estimating span of Subphase C2 and Building 8
K1410	A1	Building 48: roof beam	CH: Juniper	8850 ± 150	8290-7590	
K1411	A1	Building 48: wall post	CH: Quercus	8770 ± 150	8260-7580	
K1084	B2	Building 26: beam roof fall directly above floor	CH: Juniper	8730 ± 160	8250-7530	

* CH: Charcoal; S: Seed/nut; B: Bone.

Lab reference	Context		Material*	Radiocarbon date		Justification for exclusion
	Subphase: Location			*BP*	*Cal BC range (95%)*	
K1412	A1	Building 48: central post	CH: Pistacia	8720 ± 150	8240-7540	
K1083	A2	Building 74: central post	CH: Pistacia	8640 ± 160	8240-7370	
AA13036	A1	Outdoor area: hearth 5	S: Pistacia	8830 ± 70	8230-7680	
K1082	A2	Building 54: large basket of carbonised pistachios	S: Pistacia	8710 ± 130	8220-7560	
GrN5136	A2	Building 74: central post	CH: Pistacia	8810 ± 50	8210-7720	
P1381	A1	Building 18: burnt fill	CH: ?	8765 ± 102	8210-7590	
AA13038		Non-phased, Hearth A	Legumes	8765 ± 80	8200-7600	Insufficient contextual information
P1378	A2	Building 54: central post	CH: ?	8715 ± 100	8200-7580	
K1085	C2	Building 8: from near top of stone-lined pit	CH: Juniper	8550 ± 160	8200-7180	
AA14109	A1	Building 49: upper floor	B: Ovicaprid femur	8646 ± 69	7940-7550	Poor agreement; one of the later PPN dates despite being from Subphase A1; the only date sourced from bone; the only sample (of 7 submitted) to retain sufficient amino acids for dating; carbon contamination often causes younger dates in bone; possibly intrusive disarticulated bone.
P1379	A2	Building 54: large basket of carbonised pistachios	S: Pistacia	8546 ± 100	7940-7350	Poor agreement; two of the latest PPN dates despite being from Subphase A1; date considerably later than K1082 sourced from the same material.
GrN5063	A2	Building 54: large basket of carbonised pistachios	S: Pistacia	8640 ± 50	7790-7570	
AA13037		Non-phased, Hearth B	Legumes	7720 ± 130	7040-6360	Insufficient contextual information

* CH: Charcoal; S: Seed/nut; B: Bone.

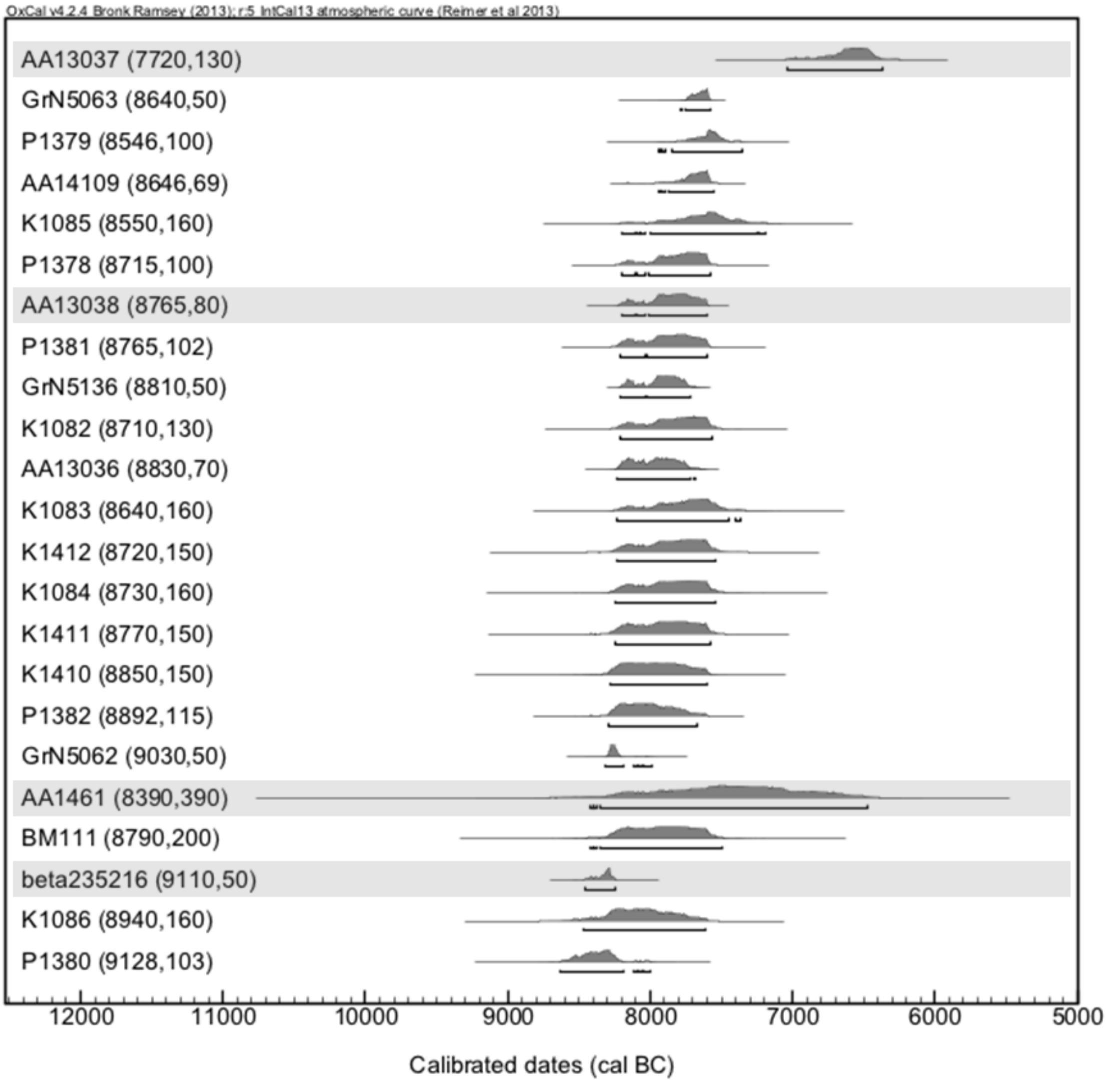


Figure 6.4. Beidha PPN radiocarbon dates (cal BC) (*n* = 23) with 95% probability distributions. Dates with insufficient contextual information highlighted in grey.

Table 6.4. Results of Chi-squared tests (χ^2) on combined Beidha PPN radiocarbon dates.

	Weighted mean (BP)	*X^2 result*	*Cal BC range (95%)*
19 dates	8798 ± 21	fail: df=18 T=60.4 (5% 28.9)	7960 - 7750
14 dates	8788 ± 29	df=13 T=6.7 (5% 22.4)	7970 - 7730

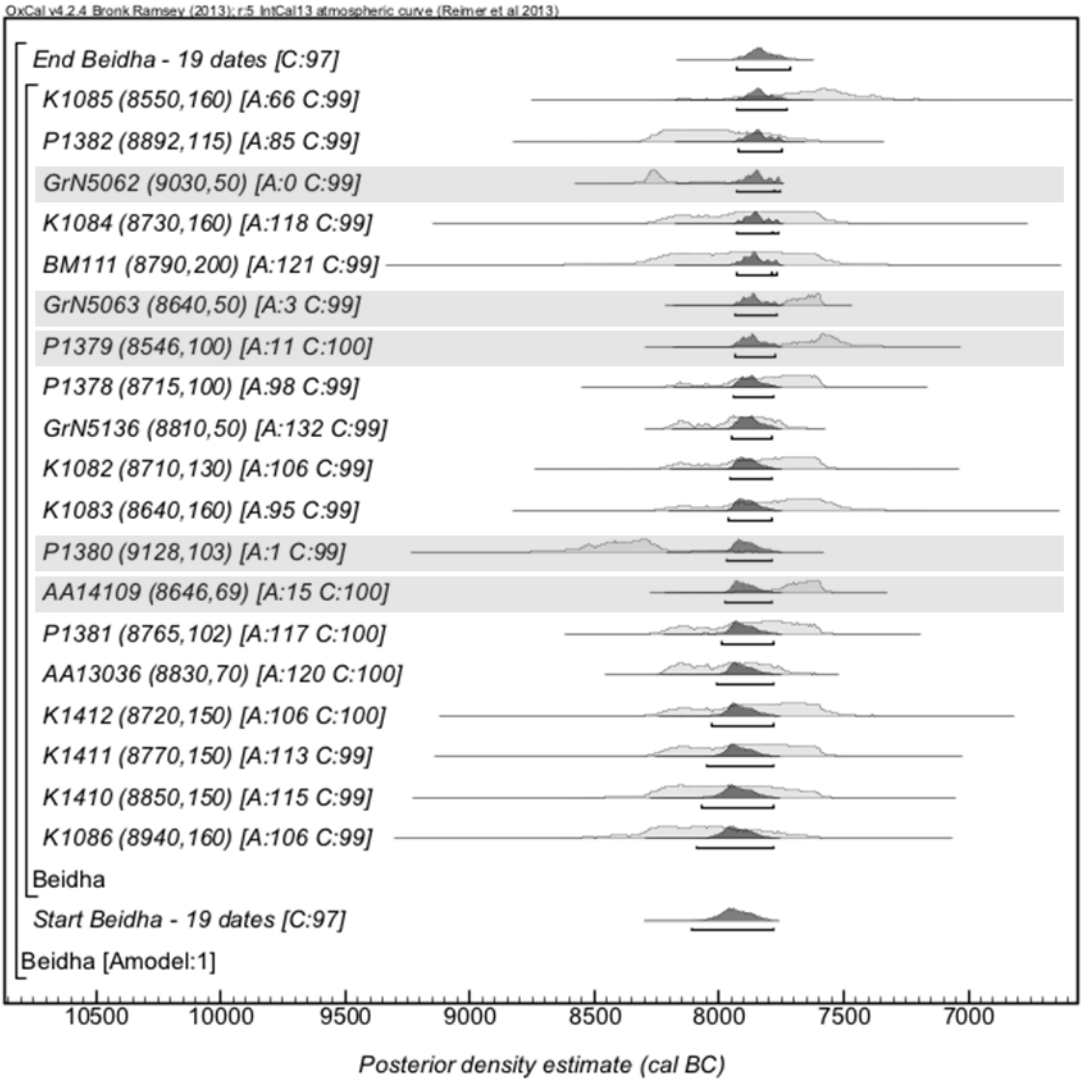


Figure 6.5. Modelled boundary (start/end) dates for Beidha PPN occupation based on posterior density estimates of calibrated dates (cal BC) by order of subphase and descending chronological order of earliest cal BC date: 1st run (*n* dates = 19). Distributions in lighter grey represent the simple radiocarbon calibrations and those in darker grey represent the posterior 95% probability distributions. Dates with poor agreement highlighted in grey.

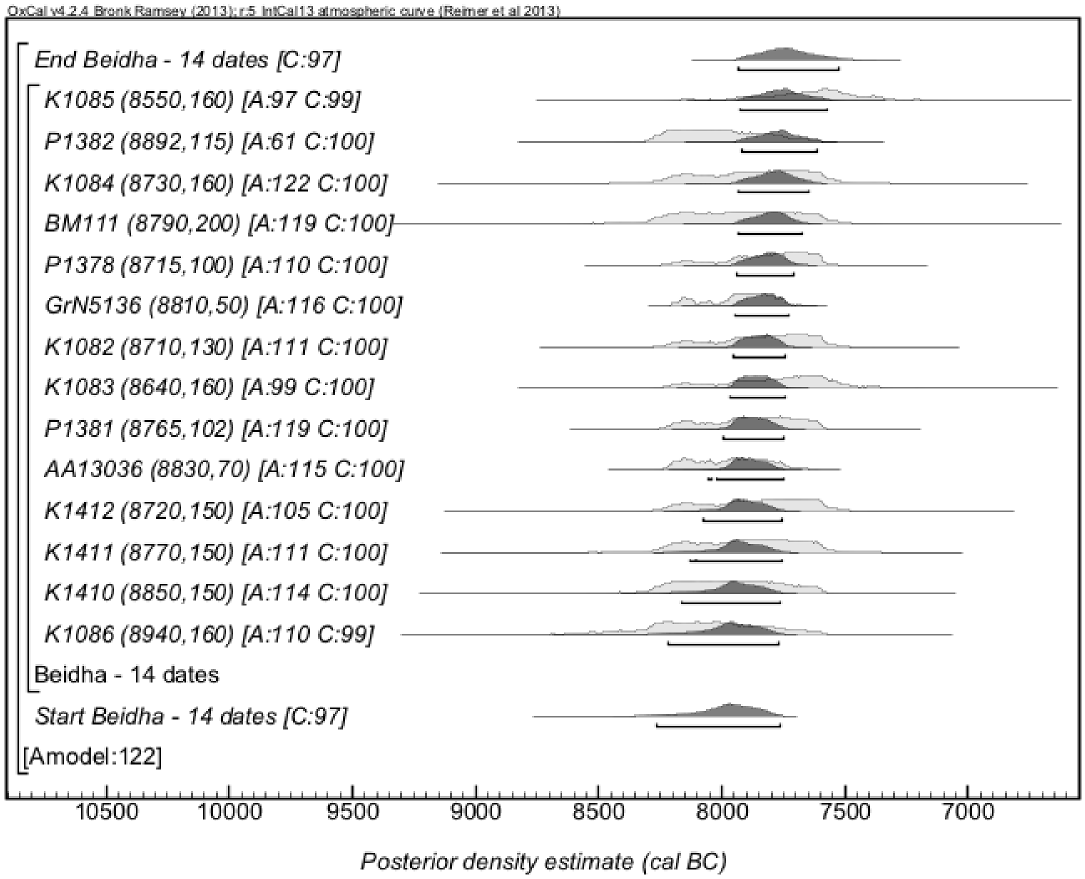


Figure 6.6. Modelled boundary (start/end) dates for Beidha PPN occupation based on posterior density estimates of calibrated dates (cal BC): 2nd run (*n* dates = 14), following removal of dates with poor agreement.

Table 6.5. Modelled boundary (start/end) dates for Beidha PPN occupation based on posterior density estimates of calibrated dates (cal BC) by order of subphase and in descending chronological order: 1st (19 dates) and 2nd (14 dates) run. Dates with poor agreement (A ≤ 60%) highlighted in grey and removed from 2nd run.

Lab reference	**Radiocarbon date range (cal BC) (95%)**	**1st run: 19 dates**			**2nd run: 14 dates**		
		Posterior density estimate range (cal BC) (95.4%)	**Indices** *Amodel=0.7* *Aoverall=1*		**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=122* *Aoverall=126.3*	
			A	*C*		*A*	*C*
Start		8120-7780		96.9	8270-7760		97.4
K1086	8470-7600	8100-7780	106.2	98.6	8220-7760	110	99.3
K1410	8290-7590	8080-7780	114.5	99.1	8170-7760	113.6	99.6
K1411	8260-7580	8060-7780	113	99.4	8130-7750	110.6	99.7
K1412	8240-7540	8030-7780	105.9	99.6	8080-7750	105.1	99.6
AA13036	8230-7680	8010-7780	120	99.6	8060-7750	115.3	99.8
P1381	8210-7590	8000-7780	117.1	99.5	8000-7740	119	99.8
AA14109	7940-7550	7980-7780	14.5	99.5			
P1380	8640-7990	7980-7780	1.4	99.4			
K1083	8240-7370	7970-7780	94.9	99.3	7970-7740	98.8	99.8
K1082	8220-7560	7960-7780	106.2	99.2	7960-7740	110.9	99.8
GrN5136	8210-7720	7950-7780	132.1	99.4	7950-7730	116.3	99.8
P1378	8200-7580	7950-7780	97.9	99.4	7950-7700	109.7	99.8
P1379	7940-7350	7940-7770	10.5	99.5			
GrN5063	7790-7570	79407770	3	99.4			
BM111	8430-7490	7940-7760	121.2	99.4	7940-7670	119.1	99.7
K1084	8250-7530	7930-7760	117.5	99.4	7940-7650	121.8	99.7
GrN5062	8320-7990	7930-7750	0	99.2			
P1382	8290-7670	7930-7750	84.6	99.0	7920-7610	61.3	99.6
K1085	8200-7180	7940-7730	66.3	98.7	7930-7570	96.8	99.3
End		7940-7710		97.2	7940-7520		97.4
Span (years)		**0-320**		**96.1**	**0-660**		**97.0**

A ‘sequence’ model was applied to the refined dataset (*n* = 14 dates) to estimate occupation span, subphase length and building use-life. Byrd’s (2005a) detailed analysis of the stratigraphic sequence at Beidha indicated a contiguous relationship, with no intermittent break, between Subphases A1 and A2 and sequential relationships, with intermittent breaks reflecting intervening subphases or earlier building periods, between Subphases A2, B2 and C2 (i.e. Subphases B1 and C1). Occupational evidence for Subphases B1 and C1 and building use-life estimates for comparable structures via archaeological, ethnographic and experimental research indicated potential ‘gap’ periods of at least 30 years for Subphase B1 and at least 70 years for Subphase C1 (Table 6.6). Based on the stratigraphic relationships between subphases, a Bayesian chronological model was structured to produce a ‘transition’ date between Subphases A1 and A2, and estimated ‘end’ and ‘start’ dates between Subphases A2, B2 and C2, with suggested minimum ‘gap’ periods of 30 years for Subphase B1 and 70 years for Subphase C1 (see Figure 5.3 for OxCal code).

Table 6.6. Archaeological evidence for and suggested minimum length of Subphases B1 and C1.

Archaeological evidence for subphase length *(Byrd 2005a: pp.46-58, 90-91)*	**Min subphase length (years)**
Subphase B1 (earlier Phase B occupation)	**30**
• Later Phase B buildings (34, 25, 26) superimposed earlier Phase B buildings (35, 40, 42). • Wall fall deposits west of later Phase B Building 25 represent large-scale levelling of earlier Phase B structure. • Remodelling of earlier Phase B Building 42. • Use-life of earlier Phase B structures potentially 35-55 years (use-life estimate for comparable earthen/masonry structures with moderate maintenance: see Table 6.1).	
Subphase C1	**70**
• “Considerable span” suggested for Phase C buildings. • Extensive remodelling of C1 buildings. • Construction of C1 Building 23 within exterior cultural deposits accumulated after construction of C1 Building 7. • Use of earlier Phase C wall by C1 Building 6. • Truncation of earlier Phase C Building 5 by C1 Building 9. • Several re-flooring episodes in C1 Building 9. • Two probable occupations of Building 1 during C1 separated by a probable period of abandonment. • At least four building episodes in C1 (as opposed to one main building episode in C2). • Use-life of C1 structures potentially 50-100 years (use-life estimate for comparable masonry structures with moderate-considerable maintenance: see Table 6.1).	

‘Phase’ subsets were constructed for each building to estimate use-life. As more than one structure occurred within Subphases A1 (Buildings 18 and 48) and A2 (Buildings 54 and 74), individual ‘building phase’ models were grouped within overall ‘subphase building phase’ models to allow for potential overlap between the dates of these structures. Based on the prior chronostratigraphic information and the considerable developments that occurred throughout the PPN occupation at Beidha, the broader span estimates based on the upper end of the 95.4% range are considered most valid.

The model indicates that the PPN occupation of Beidha began sometime between *8,220 and 7,810 cal BC* (posterior density estimates italicised herein), during the MPPNB, terminating around 600 years later sometime between *7,810 and 7,460 cal BC*, at the end of the MPPNB (Figures 6.7-6.8; Table 6.7). However, the majority of radiocarbon samples were sourced from structural elements and it is highly probable that earlier start and end dates have resulted from old wood effects (Wicks *et al.* 2016).

Modelled dates indicate that Subphase A1 spanned around 140 years, terminating sometime between *8,190 and 7,770 cal BC*, with Subphase A2 spanning around 80 years and terminating sometime between *8,160 and 7,740 cal BC* (Figures 6.7-6.8; Table 6.7). The overall estimated 260 year span for Phase A compares well with Byrd's (2005a, p.27) estimate of 300 years. The model produced a 'gap' of around 70 years between the end and start dates of Subphases A2 and B2 to account for Subphase B1, which was not directly dated. For Subphase B2, the model indicated a span of 50 years, beginning sometime between *8,080 and 7,680 cal BC* and terminating between *7,920 and 7,670 cal BC*. This produces an overall estimated span of around 120 years for Phase B, lower than Byrd's (2005a) estimate of 150 to 250 years. The model indicates a further 'gap' of around 100 years between Subphases B2 and C2 to account for Subphase C1. Modelled dates indicate that Subphase C2 began sometime between *7,810 and 7,580 cal BC* and terminated sometime between *7,810 and 7,460 cal BC*, spanning up to 80 years. The overall estimated Phase C span of around 180 years compares well with the range proposed by Byrd (2005a) (150-250 years).

The model produced building use-life estimates of 90 and 120 years for Subphase A1 Buildings 18 and 48, respectively; 60 years each for Subphase A2 Buildings 54 and 74; 50 years for Subphase B2 Building 26; and 80 years for Subphase C2 Building 8 (Figure 6.9; Table 6.7). Building use-life estimates for Subphases A2, B2 and C2 are comparable to values derived from archaeological, ethnographic and experimental research (Table 6.8). However, building use-life values for Subphase A1 are relatively high. This probably partly reflects earlier than expected start dates resulting from old wood effects (Wicks *et al.* 2016). Even if adjustments were made for old wood effects, the difference between Subphase A1 length and building use-life values would be expected to remain relatively constant. Therefore, the current values are considered suitable for the purposes of contemporaneity adjustments.

If the long span estimate for Subphase A1 Building 48 (120 years) is not due to old wood effects, this raises some questions about the generally accepted stratigraphic sequence. Building 48 and associated annex, Building 50, are the only Subphase A1 structures that were not superimposed by Subphase A2 buildings and the only Subphase A1 structures for which there is clear evidence of burning (Byrd 2005a, p.78). Byrd (2005a, p.78) argues that it is possible, although "unlikely", that Buildings 48 and 50 were utilised to the end of Subphase A2 when a conflagration destroyed much of the occupation. The long span estimate derived for Building 48 could suggest that this building was indeed occupied during Subphase A2.

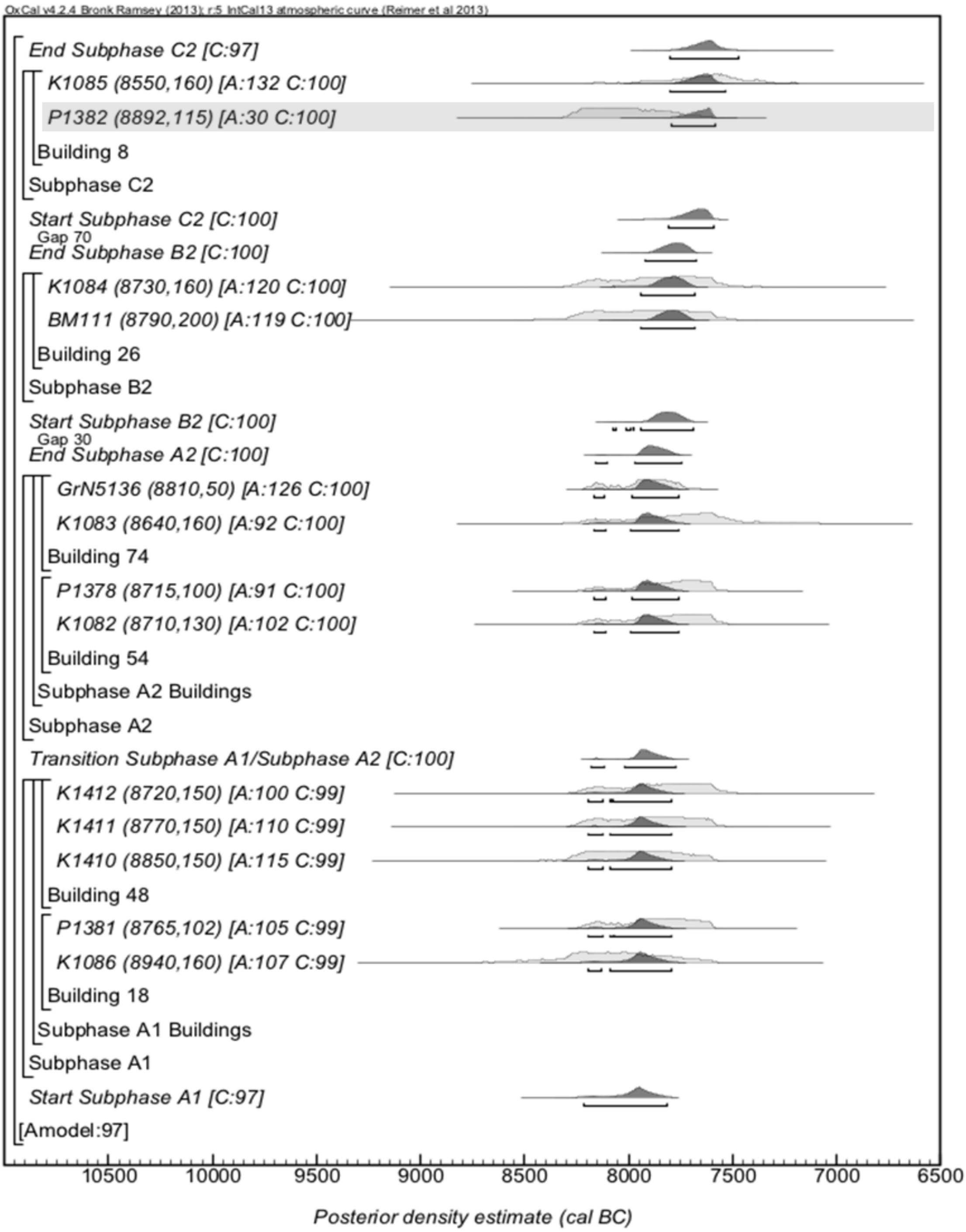


Figure 6.7. Modelled boundary (start/transition/end) dates for PPN Beidha occupation and subphases based on posterior density estimates of calibrated dates (cal BC) (*n* dates = 14). Date with poor agreement highlighted in grey.

Table 6.7. Modelled boundary (start/transition/end) dates for Beidha PPN occupation and subphases, and span (years) estimates based on posterior density estimates of calibrated dates (cal BC) by order of subphase and building in descending chronological order. Date with poor agreement highlighted in grey.

Building	**Lab reference**	**Radiocarbon date range (cal BC) (95%)**	**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=96.5 Aoverall=95.6* *A*	*C*
Start Subphase A1			8220-7810		96.5
18	K1086	8470-7600	8200-7790	106.7	99.3
	P1381	8210-7590	8200-7790	104.7	99.3
	Span Building 18		**0-90**		**99.9**
48	K1410	8290-7590	8200-7790	114.6	99.3
	K1411	8260-7580	8200-7790	110.1	99.3
	K1412	8240-7540	8200-7790	99.9	99.3
	Span Building 48		**0-120**		**99.8**
Span Subphase A1			***0-140***		***99.7***
Transition Subphase A1/A2			8190-7770		99.5
54	K1082	8220-7560	8170-7750	102.3	99.7
	P1378	8200-7580	8170-7750	91.1	99.6
	Span Building 54		**0-60**		**100**
74	K1083	8240-7370	8170-7750	92.4	99.6
	GrN5136	8210-7720	8170-7760	125.8	99.7
	Span Building 74		**0-60**		**100**
Span Subphase A2			***0-80***		***99.9***
End Subphase A2			8160-7740		99.7
		Subphase B1: Gap ≥ 30 years			
Start Subphase B2			8080-7680		99.7
26	BM111	8430-7490	7950-7680	119	99.8
	K1084	8250-7530	7950-7680	120.4	99.8
	Span Building 26		**0-50**		**100**
Span Subphase B2			***0-50***		***100***
End Subphase B2			7920-7670		99.7
		Subphase C1: Gap ≥ 70 years			
Start Subphase C2			7810-7580		99.7
8	P1382	8290-7670	7800-7580	29.5	99.6
	K1085	8200-7180	7810-7530	131.7	99.6
	Span Building 8		**0-80**		**100**
Span Subphase C2			***0-80***		***100***
End Subphase C2			7810-7460		97.4
Span Beidha			***150-600***		***97.4***

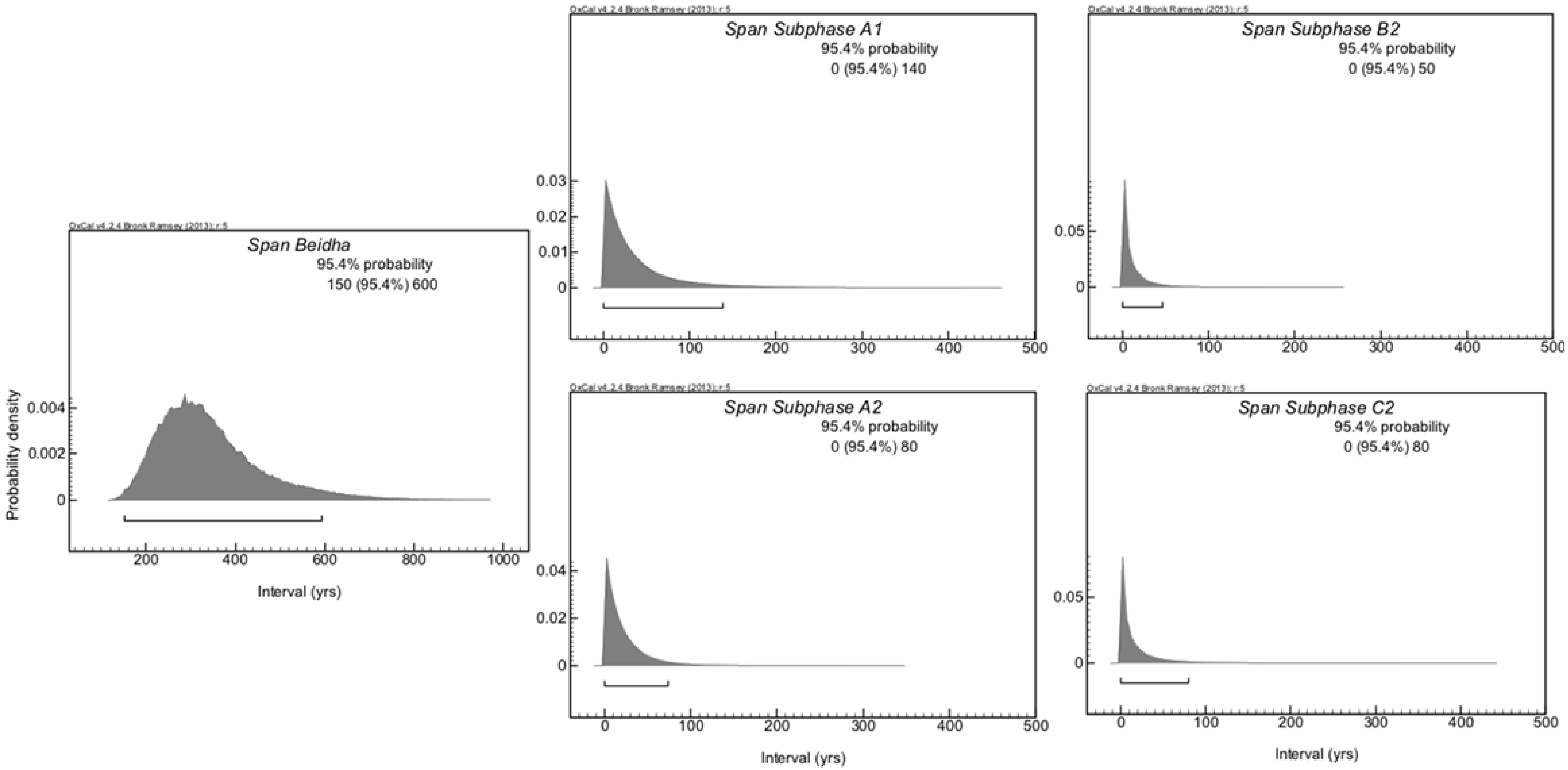


Figure 6.8. Modelled occupation span and subphase lengths for PPN Beidha.

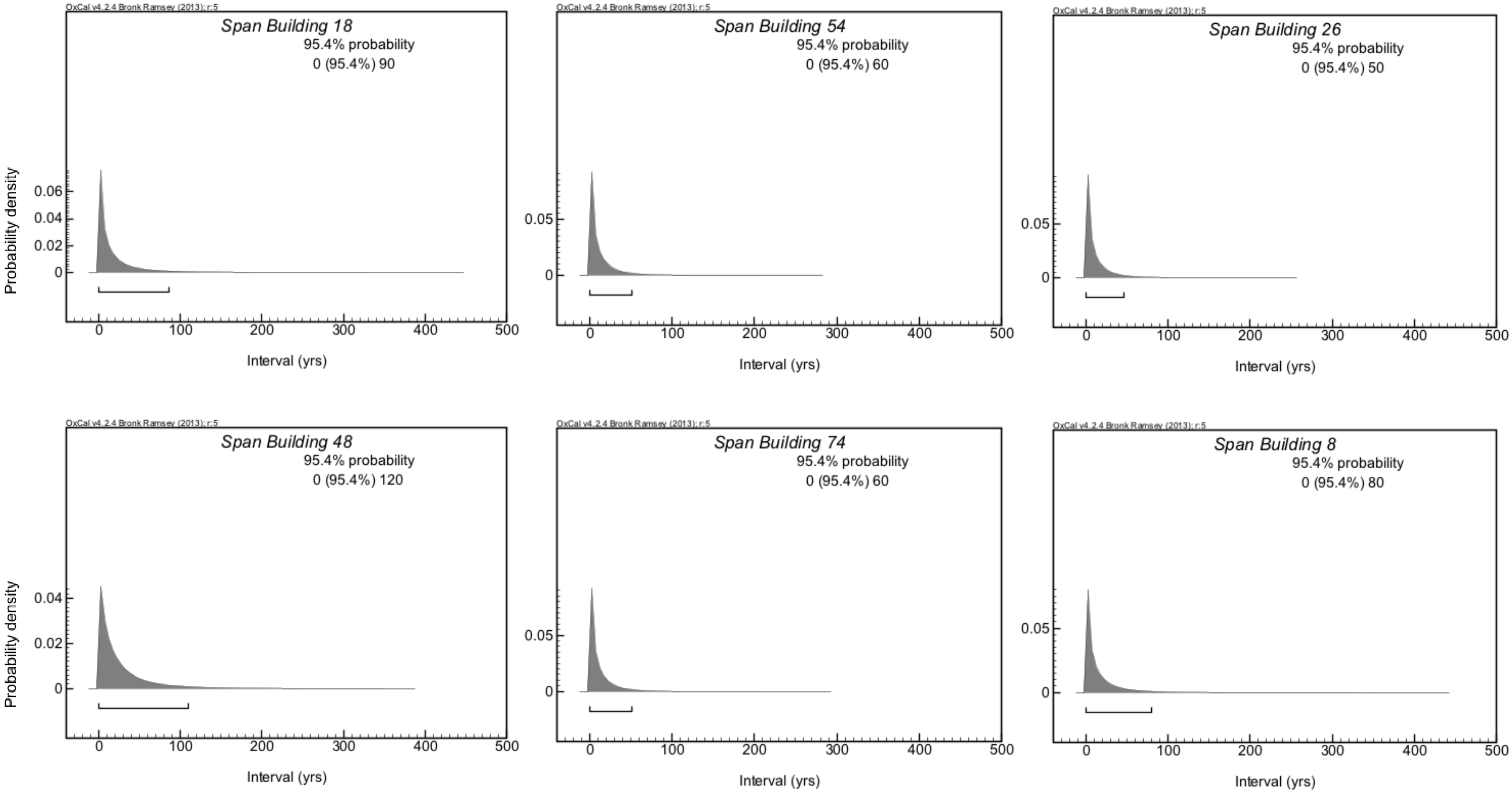


Figure 6.9. Modelled building use-life estimates for PPN Beidha.

Final subphase length and building use-life estimates for PPN Beidha

Final span estimates for use in reconstructing structural contemporaneity values are predominantly based on the maximum span values derived from the 95.4% probability posterior density estimates (Table 6.8). Modelled subphase length and average building use-life values for Subphases A1 (140 years and 100 years) and A2 (80 years and 60 years) are considered suitable. However, Subphases B2 and C2 include dates from one structure only, producing identical modelled estimates for subphase length and building use-life. For these subphases, the modelled span estimates are adjusted based on the prior chronological information and archaeological, ethnographic and experimental building use-life estimates.

For Subphase B2 and associated Building 26, the modelled spans were 50 years. Evidence exists for reuse of the western wall of Building 26 in the construction of a later Subphase B2 structure (Byrd 2005a, p.51). Therefore, if the span estimate is considered accurate for Building 26, as seems reasonable based on archaeological, ethnographic and experimental research of comparable structures (see Table 6.1), Subphase B2 must have spanned longer than 50 years. Byrd (2005a, p.84) suggests 33.3% to 50% contemporaneity in the northeastern corner of the excavated area and potentially 100% contemporaneity in the central cluster. If an average contemporaneity value of around 70% is considered reasonable for this subphase, this would equate to a Subphase B2 span of around 70 years. This falls part way between the 100 year span estimate based on Byrd's (2005a) estimate of 150 to 250 years for Phase B and the modelled estimate of 50 years for Subphase B2. A subphase length of 70 years and an average building use-life of 50 years is, therefore, considered suitable for Subphase B2 in this investigation.

For Subphase C2 and associated Building 8, the modelled spans were 80 years. The construction of Building 8 represents the beginning of Subphase C2, with abandonment of the structure probably occurring slightly prior to site abandonment (Byrd 2005a, p.178). If this use-life estimate is considered reasonable for Building 8, as is supported by research of comparable structures (see Table 6.1), Subphase C2 must have spanned marginally longer than 80 years, possibly 90 years or more. This falls part way between the 100 year span estimate based on Byrd's (2005a) estimate of 150 to 250 years for Phase C and the modelled estimate of 80 years for Subphase C2.

The building use-life estimate for Building 8 (80 years), which was considerably maintained, is probably not representative of Subphase C2 buildings, which generally demonstrate moderate to considerable maintenance. Archaeological, ethnographic and experimental research of comparable structures indicates a potential use-life of 50 to 100 years for these types of structures (see Table 6.1). Building 8 demonstrates a longer duration of use compared to other Subphase C2 structures, which were gradually abandoned throughout the subphase (Byrd 2005a, pp.93-94). A high degree of structural contemporaneity appears to have occurred at least in the earlier stages of Subphase C2, with many Subphase C1 buildings continuing in use alongside Subphase C2 structures built early in the subphase in relatively rapid succession (Byrd 2005a, p.93). To establish a population estimate for the height of Subphase C2 occupation, the average building use-life must reflect this high degree of contemporaneity, whilst being less than the span estimate derived for Building 8 (i.e. 80 years). Therefore, this investigation utilises an average building use-life of 70 years. This is part way between the suggested use-life based on comparable structures (50-100 years) and slightly lower than the modelled use-life for Building 8 (80 years).

Structural contemporaneity values were calculated by dividing the building use-life estimate by the subphase length estimate, as per the method detailed by Varien *et al.* (2007). Contemporaneity values were estimated at 71.43% for Subphases A1 and B2; 75% for Subphase A2; and 77.78% for Subphase C2. The latter is comparable to the contemporaneity value applied by Rollefson and Köhler-Rollefson (1989) (80%) to the PPNB/PPNC village of ‘Ain Ghazal, which demonstrates similar architectural features to Phase C.

Table 6.8. Radiocarbon dates (cal BC), phase/subphase span and building use-life estimates, and final structural contemporaneity values for PPN Beidha. Subphases under investigation highlighted in grey.

Phase	Subphase: Building	Byrd 2005a		Archaeological, ethnographic, experimental research		Bayesian chronological modelling			Final values	
		Span/ Building use-life (years)	*Radiocarbon date - start (cal BC) (95%)*[a]	*Construction, maintenance*[c]	*Use-life (years)*	*Posterior density estimates (cal BC) (95.4%): Span/ use-life (years)*	*Start*	*End*	***Span/ use-life (years)***	***Structural contemporaneity (%)***
Occupation span		500-800	8470-7600			600	8220-7810	7810-7460	**~600**	
Phase/subphase length										
A		300								
	A1	*(150)*[b]				140	8220-7810	8190-7770	**140**	
	A2	*(150)*				80	8190-7770	8160-7740	**80**	
B		150-250								
	B1	*(100)*				(≥ 30)				
	B2	*(100)*				50	8080-7680	7920-7670	**70**	
C		150-250								
	C1	*(100)*				(≥ 70)				
	C2	*(100)*				80	7810-7580	7810-7460	**90**	
Building use-life										
A	A1	Considerable		E/M, C	55-75				**100**	**71.43**
	Building 18			E/M, C	55-75	90				
	Building 48			E/M, C	55-75	120				
	A2	Reasonable		E/M, Mod-C	35-75				**60**	**75**
	Building 54			E/M, Mod-C	35-75	60				
	Building 74			E/M, Mod	35-55	60				
B	B2	Short (NE)/Long (Centre)		E/M, Mod	35-55				**50**	**71.43**
	Building 26			E/M, Mod	35-55	50				
C	C2	Considerable		M, Mod-C	50-100				**70**	**77.78**
	Building 8			M, C	75-100	80				

[a] Start date is earliest radiocarbon date after 7000 BC as suggested by Byrd 2005a (6,990±160 BC). Start date converted to cal BC in OxCal v.4.2.4 (Bronk Ramsey 2005; 2009).
[b] Suggested in this investigation based on Byrd's (2005a) research.
[c] Construction - E: Earthen, M: Masonry; Maintenance - Mod: Moderate, C: Considerable (see Table 6.1 for references).

6.2 Population estimates - Subphase A1

6.2.1 Housing unit method

The housing unit method (HUM) estimates population based on an estimated total number of contemporaneous dwellings and a hypothesised number of people per dwelling. In this research, the theory of nuclear family habitation is tested by applying nuclear family dwelling unit sizes ranging from three to eight people. Three methods are explored to produce total dwelling estimates. Each produces identical results as these are based on the same fundamental area measurements and proportions sourced from the site plan. Whilst Method 1 is more efficient, Methods 2 and 3 involve the calculation of a range of demographic data useful for further analysis.

Method 1: Subphase A1 assessable area (132.17 m^2) comprises 13.22% of the estimated total site extent (1,000 m^2) (Table 6.9.). Four potential dwellings were identified. This number was divided by the proportion of area assessable (0.1322) to produce a total dwelling estimate of 30.26.

Method 2: The mean excavated residential built area per dwelling, including external walls, is 18.71 m^2. Assessable built area (86.77 m^2) constitutes 65.65% of the assessable area, producing a total built area estimate of 656.5 m^2 when multiplied by the total site extent. Potential residential built area (74.85 m^2) comprises 86.26% of the assessable built area. Multiplying this proportion by the total built area estimate produces a total residential built area estimate of 566.32 m^2. Dividing the total residential built area (566.32 m^2) by the mean residential built area per dwelling (18.71 m^2) produces a total dwelling estimate of 30.26.

A simpler method for estimating total residential built area is to divide the assessable residential built area (74.85 m^2) by the proportion of area assessable (13.22%), although this bypasses calculations of additional, useful demographic data.

Method 3: The proportion of assessable area comprising potential residential built area (56.63%) was multiplied by the total site extent to produce a total residential built area estimate of 566.32 m^2. This was divided by the mean residential built area per dwelling (18.71 m^2) to produce a total dwelling estimate of 30.26.

Application of the Subphase A1 structural contemporaneity value (71.43%) produced an estimate of 21.62 contemporaneous dwellings. Multiplication of the number of dwellings by the three nuclear family sizes produced total population estimates of around 65 to 175 people.

Table 6.9. HUM population estimates for Beidha Subphase A1.

Method 1: Total potential dwelling number					**30.26**
Number of potential dwellings in the assessable area					4
Assessable area (m^2)					132.17
Estimated total site extent (m^2)					1000
Assessable area (proportion)					0.1322
Method 2: Total potential dwelling number					**30.26**
Mean potential residential built area (m^2)					18.71
Potential residential built area (m^2)	*Building 18*	*17.76*		*Building 48*	*23.51*
	Building 41	*12.77*		*Building 49*	*20.81*
Total built area estimate (m^2)					656.50
				Assessable area (m^2)	*132.17*
				Assessable built area (m^2)	*86.77*
				Assessable built area as a proportion of assessable area	*0.6565*
				Estimated total site extent (m^2)	*1000*
Residential built area as a proportion of assessable built area					0.8626
				Potential residential built area (m^2)	*74.85*
Total potential residential built area (m^2)					566.32
Method 3: Total potential dwelling number					**30.26**
Potential residential built area as a proportion of assessable area					0.5663
Total number of contemporaneous dwellings (71.43%)					21.62
Total population estimate based on nuclear family size:		**Minimum**	**3**		**64.85**
		Average	**5.5**		**118.90**
		Maximum	**8**		**172.94**

6.2.2 Residential area density coefficient

The residential area density coefficient (RADC) method estimates population based on an estimated total contemporaneous residential floor ('sleeping') area and a hypothesised residential floor area allocation per person (in this research: 1.77-5 m^2). As for the HUM, the three methods explored for estimating total residential floor area produce identical results, though each method provides a range of demographic data for further analysis (Table 6.10).

Method 1: The potential residential floor area of the four dwellings (38.84 m^2) was divided by the proportion of area assessable (0.1322) to produce a total residential floor area estimate of 293.88 m^2.

Method 2: Built area (86.77 m^2) constitutes 65.65% of the assessable area. Multiplying this proportion by the total site extent produces a total built area estimate of 656.5 m^2. Excavated potential residential floor area (38.84 m^2) constitutes 44.76% of the assessable built area. Multiplying this proportion by the total built area estimate produces a total residential floor area estimate of 293.88 m^2.

Method 3: The proportion of assessable area comprising potential residential floor area (29.39%) was multiplied by the total site extent to produce a total residential floor area estimate of 293.88 m^2.

Application of the Subphase A1 structural contemporaneity value (71.43%) produced an estimate of 209.92 m^2 contemporaneous residential floor area. This was divided by the three RADCs to produce total population estimates of around 40 to 120 people.

Table 6.10. RADC population estimates for Beidha Subphase A1.

Method 1: Total potential residential floor area (m^2)					**293.88**
Potential residential floor area (m^2)					38.84
Potential residential floor area (m^2)	*Building 18*	*9.23*		*Building 48*	*13.88*
	Building 41	*6.50*		*Building 49*	*9.23*
Assessable area (m^2)					132.17
Estimated total site extent (m^2)					1000
Assessable area (proportion)					0.1322
Method 2: Total potential residential floor area (m^2)					**293.88**
Total built area estimate (m^2)					656.50
				Assessable area (m^2)	*132.17*
				Assessable built area (m^2)	*86.77*
				Assessable built area as a proportion of assessable area	*0.6565*
				Estimated total site extent (m^2)	*1000*
Potential residential floor area as a proportion of assessable built area					0.4476
				Potential residential floor area (m^2)	*38.84*
Method 3: Total potential residential floor area (m^2)					**293.88**
Potential residential floor area as a proportion of assessable area					0.2939
Total contemporaneous residential floor area (m^2) (71.43%)					209.92
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**			**118.60**
	Average	**3.3**			**63.61**
	Maximum	**5**			**41.98**

6.2.3 Storage provisions formulae

The storage provisions formulae (SPF) estimate population size and dwelling occupant numbers from available residential floor area. There are three SPF based on different amounts of hypothesised personal annual storage allowance in the residential floor area, as follows:

no storage: $P = 0.3944A - 0.375$

moderate storage (0.46 m^3 per person): $P = 0.2477A + 0.0339$

maximum storage (2 x 0.46 m^3 per person): $P = 0.1903A + 0.3976$

Method 1: The variables for Method 1 are defined as follows:

A Total contemporaneous residential floor area (m^2)

P Total (adult) population

The estimated total contemporaneous residential floor area (A) for Subphase A1 calculated via the RADC method is 209.92 m^2. Application of the SPF Method 1 produced population (P) estimates of around 40 people (maximum storage) to 80 people (no storage) (Table 6.11; Figure 6.10).

Method 2: The variables for Method 2 are defined as follows:

A Mean residential floor area of complete dwellings (m^2)

P Number of people (i.e. adults) per dwelling

The mean residential floor area of complete dwellings (A) for Subphase A1 is 11.56 m^2. Application of the SPF Method 2 produced dwelling unit size (P) estimates of around 2.6 people (maximum storage) to 4.2 people (no storage). Multiplication of these estimates by the estimated total number of contemporaneous dwellings derived via the HUM ($n = 21.62$) produced total population estimates of around 55 people (maximum storage) to 90 people (no storage).

There is no evidence for built-in storage features within Subphase A1 dwellings and given the reliance on hunter-gatherer subsistence strategies, including communal food-related activities, and evidence for annexes associated with dwellings, it is improbable that the maximum amount of storage occurred within the residential floor area. Bitumen baskets and basket fragments uncovered in Buildings 18 and 48 indicate some residential storage. Whether this reflects on floor or elevated storage remains unclear. Based on this evidence, formulae reflecting limited (none to moderate) residential storage are considered most suitable for Beidha Subphase A1. These formulae produce a mean population estimate of around 55 to 85 people.

Table 6.11. SPF population and people per dwelling estimates for Beidha Subphase A1. Suggested amount of storage provision highlighted in grey.

			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P)											
A	=	209.92	0.3944 x 209.92	=	82.79	0.2477 x 209.92	=	52.00	0.1903 x 209.92	=	39.95
P	=	?	82.79 - 0.375	=	82.42	52 + 0.0339	=	52.03	39.95 + 0.3976	=	40.35
			P	**=**	**82.42**	**P**	**=**	**52.03**	**P**	**=**	**40.35**
Method 2: People per dwelling (P) and total population estimates											
A	=	11.56	0.3944 x 11.56	=	4.56	0.2477 x 11.56	=	2.86	0.1903 x 11.56	=	2.20
P	=	?	4.56 - 0.375	=	4.18	2.86 + 0.0339	=	2.90	2.20 + 0.3976	=	2.56
			P	**=**	**4.18**	**P**	**=**	**2.90**	**P**	**=**	**2.56**
						Total number of contemporaneous dwellings					*21.62*
		Total population			**90.45**			**62.63**			**55.32**
Mean total population					**86.44**			**57.33**			**47.83**

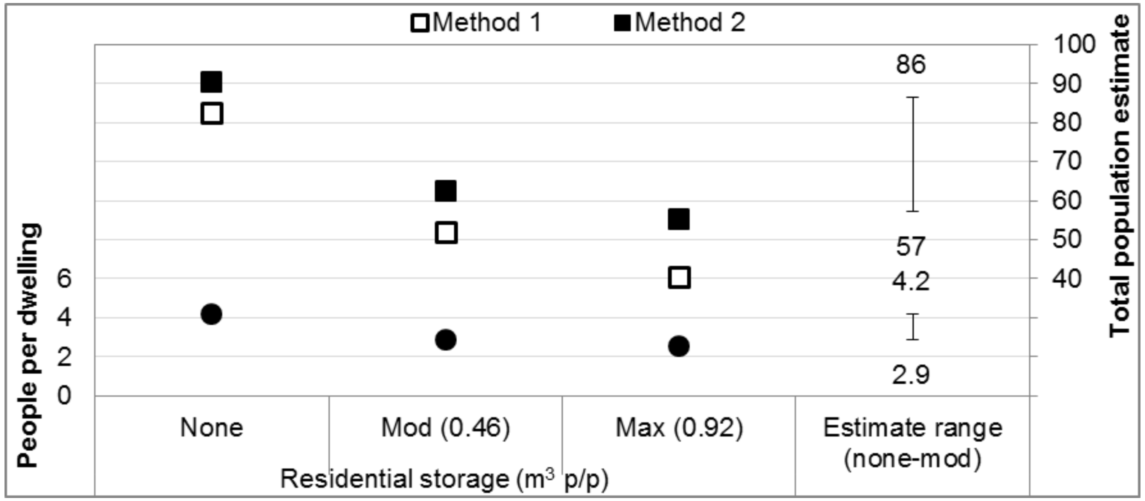


Figure 6.10. SPF population and people per dwelling estimates for Beidha Subphase A1.

6.2.4 Naroll's (1962) allometric growth formula

The SPF was considered the most empirically robust and reliable method for estimating population parameters (see Section 10.2.1). Therefore, the SPF population estimates based on the applicable storage provisions (Subphase A1: none to moderate) are employed as the P (population) variable within the allometric growth formulae (AGF).

Two methods are explored in the application of Naroll's (1962) AGF (AGF1) ($A = a \times P^b$), where constants and variables are defined as follows:

A	Total built floor area (m^2)
a	Initial growth index (21.7)
P	Total population
b	Scaling exponent (0.84195)

Method 1: To estimate total built floor area, the value of $P^{0.84195}$ was multiplied by the initial growth index (*a* = 21.7) (Table 6.12). This produced total built floor area (A) estimates of between 656.06 m^2 (moderate storage) and 926.96 m^2 (no storage). These estimates are considerably higher than the estimated total built floor area based on the excavated evidence (A = 342.21 m^2) (Table 6.13). The total built floor area estimates based on Naroll's (1962) formula were divided by the corresponding SPF population estimate to calculate built floor area per person of 10.72 m^2 (no storage) to 11.44 m^2 (moderate storage). These values compare well with Naroll's (1962) proposed universal constant of 10 m^2 roofed/built floor area per person (see Section 4.1.4).

Built floor area per person estimates were multiplied by the proportion of residential floor area in built floor area as derived from the excavated evidence (85.88%) to produce residential floor area per person (RADC) estimates of 9.21 m^2 (no storage) to 9.83 m^2 (moderate storage). These are considerably higher than RADCs calculated from the SPF population estimate range and the estimated total contemporaneous residential floor area in this investigation (2.43-3.66 m^2 per person).

Method 2: The total built floor area estimate derived from the excavated evidence (A = 342.21 m^2) and the Subphase A1 SPF population estimates were used to re-calculate Naroll's (1962) initial growth index (*a* = 21.7). This produced initial growth indices (*a*) of 8.01 (no storage) to 11.32 (moderate storage). These are considerably lower than Naroll's (1962) original index.

Table 6.12. Application of Naroll's (1962) AGF1 to Beidha Subphase A1.

Data required		
SPF population estimate (P) based on amount of storage:	None	86.44
	Moderate	57.33
	Maximum	47.83
Residential floor area as a proportion of built floor area (%)		85.88
Total built floor area (m^2) (A)		*342.21*
Built floor area in assessable area (m^2)		*45.23*
Proportion of site assessable (%)		*13.22*
Total residential floor area (m^2) (RADC method)		*293.88*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	3.96
	Moderate	5.97
	Maximum	7.15
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.43
	Moderate	3.66
	Maximum	4.39
Total contemporaneous residential floor area (m^2) (RADC method)		209.92

		$A = a \times P^b$					
Amount of storage:	*None*	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 86.44^{0.84195}$**		
		P	=	86.44	$86.44^{0.84195}$	=	42.72
		a	=	21.7	21.7 x 42.72	=	926.96
		b	=	0.84195	**A**	**=**	**926.96**
		Built floor area per person (m^2)					**10.72**
		RADC (m^2 per person)					**9.21**
		Residential floor area as a proportion of built floor area					*85.88*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	342.21	**$342.21 = a \times 86.44^{0.84195}$**		
		P	=	86.44	$86.44^{0.84195}$	=	42.72
		a	=	?	342.21/42.72	=	8.01
		b	=	0.84195	***a***	**=**	**8.01**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 57.33^{0.84195}$**		
		P	=	57.33	$57.33^{0.84195}$	=	30.23
		a	=	21.7	21.7 x 30.23	=	656.06
		b	=	0.84195	**A**	**=**	**656.06**
		Built floor area per person (m^2)					**11.44**
		RADC (m^2 per person)					**9.83**
		Residential floor area as a proportion of built floor area					*85.88*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	342.21	**$342.21 = a \times 57.33^{0.84195}$**		
		P	=	57.33	$57.33^{0.84195}$	=	30.23
		a	=	?	342.21/30.23	=	11.32
		b	=	0.84195	***a***	**=**	**11.32**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 47.83^{0.84195}$**		
		P	=	47.83	$47.83^{0.84195}$	=	25.96
		a	=	21.7	21.7 x 25.96	=	563.27
		b	=	0.84195	**A**	**=**	**563.27**
		Built floor area per person (m^2)					**11.78**
		RADC (m^2 per person)					**10.11**
		Residential floor area as a proportion of built floor area					*85.88*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	342.21	**$342.21 = a \times 47.83^{0.84195}$**		
		P	=	47.83	$47.83^{0.84195}$	=	25.96
		a	=	?	342.21/25.96	=	13.18
		b	=	0.84195	***a***	**=**	**13.18**

Table 6.13. Summary of estimates for application of Naroll's (1962) AGF1 to Beidha Subphase A1. Estimates based on suggested amount of storage provision in the residential floor area highlighted in grey.

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (86.44)	*Moderate (57.33)*	*Maximum (47.83)*		*None (86.44)*	*Moderate (57.33)*	*Maximum (47.83)*
Total built floor area (m^2)	926.96	656.06	563.27	342.21			
Built floor area per person (m^2)	10.72	11.44	11.78		3.96	5.97	7.15
RADC (m^2 per person)	9.21	9.83	10.11		2.43	3.66	4.39
Initial growth index	8.01	11.32	13.18				

6.2.5 Wiessner's (1974) allometric growth formulae

Wiessner's (1974) allometric growth formulae (AGF2) for open ($A = a \times P^2$), village ($A = a \times P^1$) and urban ($A = a \times P^{0.6667}$) settlements were applied using the estimated total site extent as the A variable and SPF population estimates as the P variable to determine the value of the initial growth index (*a*). Variables and constants are defined as follows:

A	Total site extent (m^2)
a	Initial growth index
P	Total population
b	Scaling exponent (open: 2; village: 1; urban: 0.6667)

Wiessner's (1974) AGF2 produced open, village and urban initial growth indices of 0.13 (no storage) to 0.3 (moderate storage); 11.57 to 17.44; and 51.15 to 67.25, respectively (Table 6.14). The AGF2 for open and village settlements only are considered suitable for this subphase. This is due to the low estimated population size; the formative nature of the village; the enduring hunter-gatherer social processes, architectural forms and settlement layout; and the lack of multi-storey structures.

Table 6.14. Application of Wiessner's (1974) AGF2 to Beidha Subphase A1. Estimates based on suggested amount of storage provision and applicable settlement types highlighted in grey.

Data required		
Total site extent (m^2) (A)		1000
SPF population estimate (P) based on amount of storage:	None	86.44
	Moderate	57.33
	Maximum	47.83

Amount of storage:							
				A = *a* x P^b			
None	**Open settlements**				**1000 = *a* x 86.44^2**		
	A	=	1000				
	P	=	86.44	86.44^2		=	7471.15
	a	=	?	1000/7471.15		=	0.13
	b	=	2	***a***		**=**	**0.13**
	Village settlements				**1000 = *a* x 86.44^1**		
	A	=	1000				
	P	=	86.44	86.44^1		=	86.44
	a	=	?	1000/86.44		=	11.6
	b	=	1	***a***		**=**	**11.57**
	Urban settlements				**1000 = *a* x 86.44$^{0.6667}$**		
	A	=	1000				
	P	=	86.44	$86.44^{0.6667}$		=	19.55
	a	=	?	1000/19.55		=	51.15
	b	=	0.6667	***a***		**=**	**51.15**
Moderate	**Open settlements**				**1000 = *a* x 57.33^2**		
	A	=	1000				
	P	=	57.33	57.33^2		=	3286.98
	a	=	?	1000/3286.98		=	0.30
	b	=	2	***a***		**=**	**0.30**
	Village settlements				**1000 = *a* x 57.33^1**		
	A	=	1000				
	P	=	57.33	57.33^1		=	57.33
	a	=	?	1000/57.33		=	17.4
	b	=	1	***a***		**=**	**17.44**
	Urban settlements				**1000 = *a* x 57.33$^{0.6667}$**		
	A	=	1000				
	P	=	57.33	$57.33^{0.6667}$		=	14.87
	a	=	?	1000/14.87		=	67.25
	b	=	0.6667	***a***		**=**	**67.25**
Maximum	**Open settlements**				**1000 = *a* x 47.83^2**		
	A	=	1000				
	P	=	47.83	47.83^2		=	2288.12
	a	=	?	1000/2288.12		=	0.44
	b	=	2	***a***		**=**	**0.44**
	Village settlements				**1000 = *a* x 47.83^1**		
	A	=	1000				
	P	=	47.83	47.83^1		=	47.83
	a	=	?	1000/47.83		=	20.9
	b	=	1	***a***		**=**	**20.91**
	Urban settlements				**1000 = *a* x 47.83$^{0.6667}$**		
	A	=	1000				
	P	=	47.83	$47.83^{0.6667}$		=	13.18
	a	=	?	1000/13.18		=	75.88
	b	=	0.6667	***a***		**=**	**75.88**

Initial growth indices for:	*SPF population estimate based on* amount *of storage:* None (86.44)	*Moderate (57.33)*	*Maximum (47.83)*
Open settlements	0.13	0.30	0.44
Village settlements	11.57	17.44	20.91
Urban settlements	51.15	67.25	75.88

6.2.6 Settlement population density coefficient

The settlement population density coefficient (SPDC) method calculates (1) population size from commonly utilised SPDCs and (2) SPDCs from HUM, RADC and SPF population estimate ranges.

Method 1: To calculate population size, the total site extent (0.1 ha) was multiplied by the three commonly utilised SPDCs (90, 150 and 294 people/ha). This produced total population estimates of nine, 15 and 29.4 people, respectively (Table 6.15; Figure 6.11). When multiplied by the proportion of assessable excavated area (13.22%), these estimates equate to a total population of 1.19, 1.98 and 3.89 people in the assessable area, and average dwelling unit sizes of 0.42, 0.69 and 1.36 people based on an estimated 2.86 contemporaneously occupied dwellings in the assessable area.

Method 2: To calculate SPDCs, population estimates derived from the HUM (P = 64.85-172.94), RADC (P = 41.98-118.6) and applicable SPF (P = 57.33-86.44) were divided by the total site extent (0.1 ha). This produced density values of around 650 to 1,730 people per hectare (HUM), 420 to 1,190 people per hectare (RADC) and 570 to 960 people per hectare (SPF). These values are substantially higher than the commonly utilised SPDCs (90-294 people per hectare).

Table 6.15. Population estimates and SPDCs for Beidha Subphase A1 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

Data required	
Total site extent (ha)	0.1
Proportion of site assessable (%)	13.22
Number of contemporaneous dwellings in the assessable area	2.86
Dwellings in assessable area	*4*
Contemporaneity value (%)	*71.43*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	9	15	29.4
Population in the assessable area	*1.19*	*1.98*	*3.89*
People per dwelling in the assessable area	*0.42*	*0.69*	*1.36*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	64.85	118.90	172.94	648.53	1188.97	1729.41
RADC	41.98	63.61	118.60	419.84	636.12	1185.99
SPF	57.33	-	86.44	573.32	-	864.36

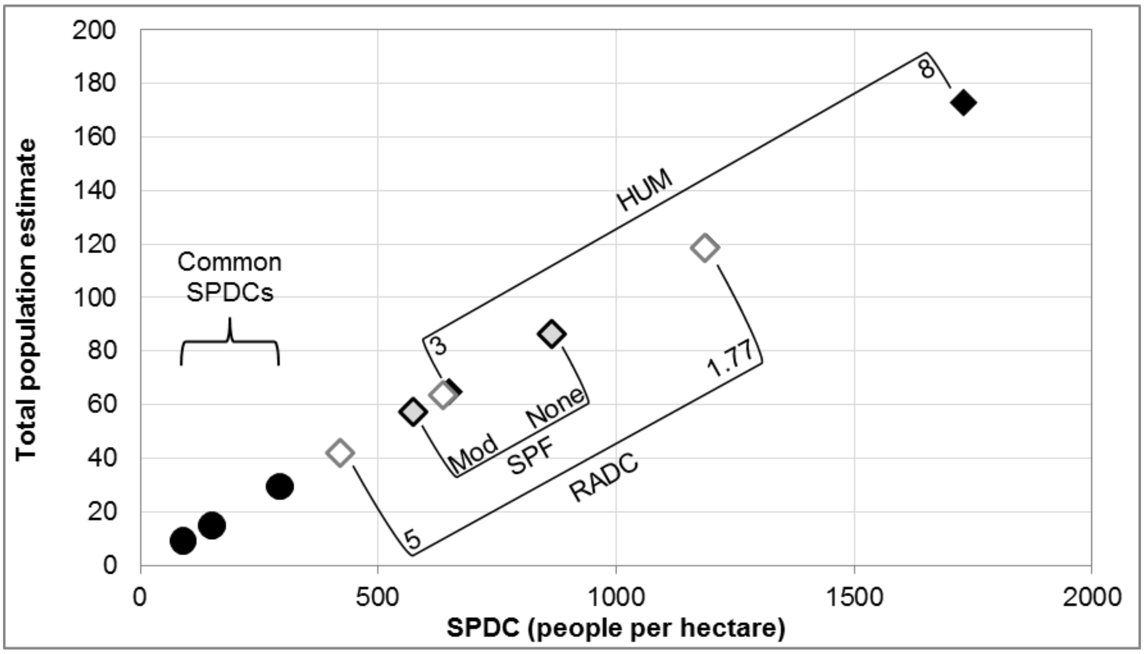


Figure 6.11. Population estimates and SPDCs for Beidha Subphase A1 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates. Variables utilised in HUM, RADC and SPF population estimates indicated.

6.2.7 Summary of estimates

Table 6.16. Summary of estimates for Beidha Subphase A1. Values highlighted in grey include SPF estimates, which are the final estimates used in AGF and comparative analysis; the most plausible amount of storage provision in the residential floor area; appropriate settlement types for Wiessner's (1974) AGF2; and contemporaneous proportions utilised in systematic methodologies.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		21.62	*209.92*	*0.1*
HUM	64.85-172.94	3-8	1.21-3.24	648.53-1729.41
RADC	41.98-118.6	1.94-5.49	1.77-5	419.84-1185.99
SPF1	57.33-86.44	2.65-4	2.43-3.66	573.32-864.36
SPF2[a]	-	2.9-4.18	-	-
AGF1[a]	-	-	9.21-9.83	-
SPDC	9-29.4	0.42-1.36	7.14-23.32	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (86.44)	*Moderate (57.33)*	*Maximum (47.83)*
Naroll's (1962) AGF1		8.01	11.32	13.18
Wiessner's (1974) AGF2	Open settlements	0.13	0.30	0.44
	Village settlements	11.57	17.44	20.91
	Urban settlements	51.15	67.25	75.88

Additional demographic data			
			Contemporaneous (71.43%)
Proportion (%) of assessable area comprising:	Built area	65.65	46.89
	Residential built area	56.63	40.45
	Built floor area [b]	34.22	24.44
	Residential floor area	29.39	20.99
Proportion (%) of assessable built area comprising:	Residential built area	86.26	
	Built floor area [c]	52.13	
	Residential floor area	44.76	
Proportion (%) of built floor area comprising residential floor area		85.88	
Mean residential floor area of complete dwellings (m^2)		11.56	

[b] Based on assessable area (132.17 m^2) and built floor area (45.23 m^2).

[c] Based on assessable built area (86.77 m^2) and built floor area (45.23 m^2).

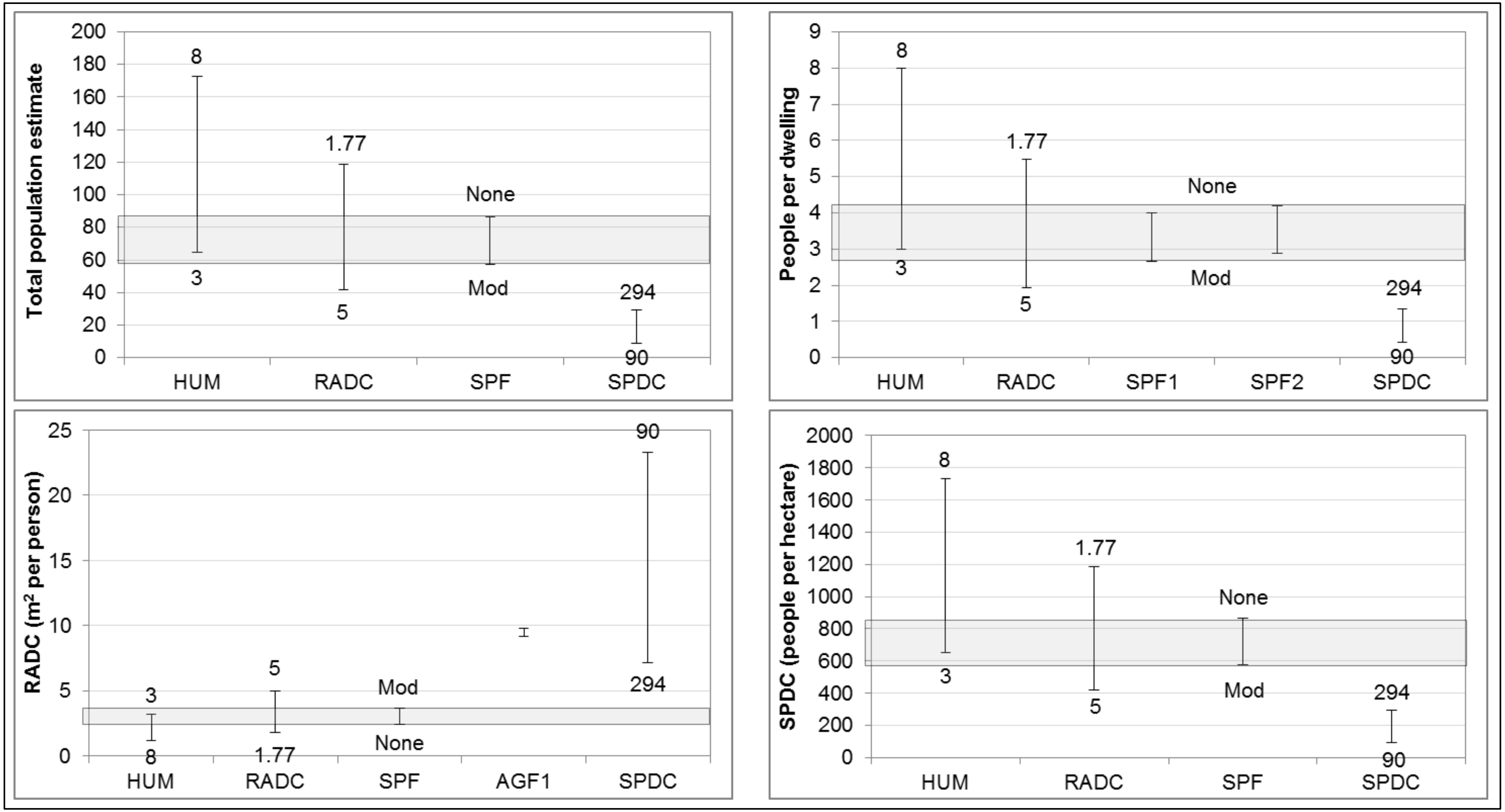


Figure 6.12. Summary of estimate ranges for Beidha Subphase A1. Values on range bars indicate the variables included in the final estimate range (i.e. HUM: nuclear family size - 3-8 people; RADC: residential floor area per person - 1.77-5 m^2; SPF: storage provisions in residential floor area - none to moderate; SPDC: 90-294 people per hectare). SPF estimate ranges are considered most valid and are highlighted in grey for comparative analysis.

6.3 Population estimates - Subphase A2

6.3.1 Housing unit method

The total number of dwellings in Subphase A2 was estimated at around 61. Application of the Subphase A2 structural contemporaneity value (75%) produced an estimate of 46 contemporaneous dwellings (Table 6.17).

The limited mean residential floor area of complete dwellings in Subphase A2 (7.26 m^2) allowed exclusion of the average (5.5 people) and maximum (8 people) nuclear family sizes from the final estimate range as these were deemed to produce insufficient residential floor area space allowance (RADC = 1.32 m^2 and 0.91 m^2 per person, respectively). The lowest RADCs derived from comparative ethnographic examples are 1.86 m^2 per person for Aboriginal Californian settlements in which dwellings were occupied by nuclear families of six to eight occupants (Cook and Heizer 1968) and 2.16 m^2 per person for dwellings without internal fireplaces in the Arctic Circle (Hayden *et al.* 1996). The lowest RADC employed in this investigation is 1.77 m^2 based on an average maximum modern human sleeping space requirement (Hemsley 2008). When based on the minimum nuclear family size only (3 people), the HUM produced a Subphase A2 population estimate of around 140 people.

6.3.2 Residential area density coefficient

The total residential floor area was estimated at around 400 m^2 (Table 6.18). Based on a total contemporaneous residential floor area estimate of 300 m^2, the total population was estimated at around 60 to 170 people.

6.3.3 Storage provisions formulae

Application of the SPF produced population estimates of around 55 people (maximum storage) to 115 people (no storage), and dwelling unit size estimates of around 1.7 people (maximum storage) to 2.5 people (no storage) (Table 6.19; Figure 6.13). Evidence exists for possible permanent storage (i.e. a small pit) and more ephemeral storage (i.e. a pistachio basket) within Building 54. However, no other storage features were uncovered. The continued reliance on hunter-gatherer subsistence strategies, evidence for communal food-related activities and annexes associated with dwellings suggest that the maximum amount of storage did not occur in the residential floor area. Therefore, formulae reflecting limited (none to moderate) residential storage are considered most suitable for Beidha Subphase A2. These formulae produce a population estimate of around 80 to 115 people, and a dwelling unit size estimate of around 1.8 to 2.5 people.

6.3.4 Naroll's (1962) allometric growth formula

Utilising the applicable SPF population estimates as the P variable, Naroll's (1962) AGF1 produced total built floor area (A) estimates of around 860 m^2 (no storage) to 1,180 m^2 (moderate storage). These are considerably higher than the total built floor area estimate derived from the excavated evidence (595.31 m^2) (Table 6.20). Built floor area per person was estimated at 10.24 m^2 (no storage) to 10.88 m^2 (moderate storage). This compares well with Naroll's constant of 10 m^2 per person. These values were converted to 6.81 m^2 (no storage) and 7.24 m^2 (moderate storage) residential floor area per person. These are considerably higher than values derived from the archaeological evidence in this investigation (2.57-3.76 m^2 per person).

The AGF1 initial growth index (*a*) was re-calculated at 10.91 (no storage) to 15.04 (moderate storage). These are considerably lower than Naroll's (1962) original index (*a* = 21.7).

6.3.5 Wiessner's (1974) allometric growth formulae

Utilising the applicable SPF population estimates as the P variable, Wiessner's (1974) AGF2 produced open, village and urban initial growth indices of 0.15 (no storage) to 0.32 (moderate storage); 17.3 to 25.34; and 84.26 to 108.67, respectively (Table 6.21). Due to the continued hunter-gatherer social, architectural and spatial elements; the potential for settlement sprawl at this relatively low population size; and the lack of multi-storey structures, the formulae for open and village settlements only are considered suitable for Subphase A2.

6.3.6 Settlement population density coefficient

The commonly utilised SPDCs (90, 150 and 294 people/ha) produced total population estimates of 18, 30 and 58.8 people (Table 6.22; Figure 6.14). This equates to a population of 2.64, 4.4 and 8.63 people in the assessable area, respectively, and an average dwelling unit size of 0.39, 0.65 and 1.28 people in the assessable area, based on 6.75 contemporaneous dwellings.

Population estimates calculated via micro-level methods produced density estimates of around 700 (HUM), 300 to 840 (RADC), and 400 to 580 (SPDC) people per hectare, respectively. All SPDC estimates based on the population estimate ranges derived from the HUM, RADC and SPF methods exceed the commonly utilised values. The SPDC based on the HUM far exceeds the maximum value (294 people/ha) despite being based on the minimum nuclear family size (3 people) only.

Table 6.17. HUM population estimates for Beidha Subphase A2. Estimate/s based on applicable nuclear family size/s highlighted in grey.

Method 1: Total potential dwelling number				**61.32**
Number of potential dwellings in the excavated area				9
Assessable area (m^2)				293.53
Estimated total site extent (m^2)				2000
Assessable area (proportion)				0.1468
Method 2: Total potential dwelling number				**61.32**
Mean potential residential built area (m^2)				12.98
Potential residential built area (m^2)	*Building 33*	*12.53*	*Building 55*	*7.63*
	Building 38	*17.66*	*Building 56*	*12.31*
	Building 51	*9.87*	*Building 74*	*14.72*
	Building 53	*13.44*	*Building 83*	*11.47*
	Building 54	*17.17*		
Total built area estimate (m^2)				1144.28
			Assessable area (m^2)	*293.53*
			Assessable built area (m^2)	*167.94*
			Assessable built area as a proportion of assessable area	*0.5721*
			Estimated total site extent (m^2)	*2000*
Residential built area as a proportion of assessable built area				0.6955
			Potential residential built area (m^2)	*116.81*
Total potential residential built area (m^2)				795.89
Method 3: Total potential dwelling number				**61.32**
Potential residential built area as a proportion of assessable area				0.3979
Total number of contemporaneous dwellings (75%)				45.99
Total population estimate based on nuclear family size:	**Minimum**	**3**		**137.98**
	Average	**5.5**		**252.96**
	Maximum	**8**		**367.94**

Table 6.18. RADC population estimates for Beidha Subphase A2.

Method 1: Total potential residential floor area (m²)				**396.09**
Potential residential floor area (m²)				58.13
Potential residential floor area (m²)	*Building 33*	*3.68*	*Building 55*	*4.82*
	Building 38	*10.31*	*Building 56*	*4.45*
	Building 51	*4.98*	*Building 74*	*8.07*
	Building 53	*7.02*	*Building 83*	*4.77*
	Building 54	*10.03*		
Assessable area (m²)				293.53
Estimated total site extent (m²)				2000
Assessable area (proportion)				0.1468
Method 2: Total potential residential floor area (m²)				**396.09**
Total built area estimate (m²)				1144.28
			Assessable area (m²)	*293.53*
			Assessable built area (m²)	*167.94*
			Assessable built area as a proportion of assessable area	*0.5721*
			Estimated total site extent (m²)	*2000*
Potential residential floor area as a proportion of assessable built area				0.3461
			Potential residential floor area (m²)	*58.13*
Method 3: Total potential residential floor area (m²)				**396.09**
Potential residential floor area as a proportion of assessable area				0.1980
Total contemporaneous residential floor area (m²) (75%)				297.07
Total population estimate based on RADC (m²):	**Minimum**	**1.77**		**167.84**
	Average	**3.3**		**90.02**
	Maximum	**5**		**59.41**

Table 6.19. SPF population and people per dwelling estimates for Beidha Subphase A2.

	Storage provisions formulae (m³ residential storage per person)		
	None	*Moderate (0.46)*	*Maximum (2 x 0.46)*
Method 1: Total population (P) based on total contemporaneous residential floor area (297.07 m²)			
Total population (P)	116.79	73.62	56.93
Method 2: People per dwelling (P) based on mean residential floor area of complete dwellings (7.26 m²) and total population based on total number of contemporaneous dwellings (45.99)			
People per dwelling (P)	2.49	1.83	1.74
Total population	114.44	84.27	80.07
Mean total population	**115.62**	**78.94**	**68.50**

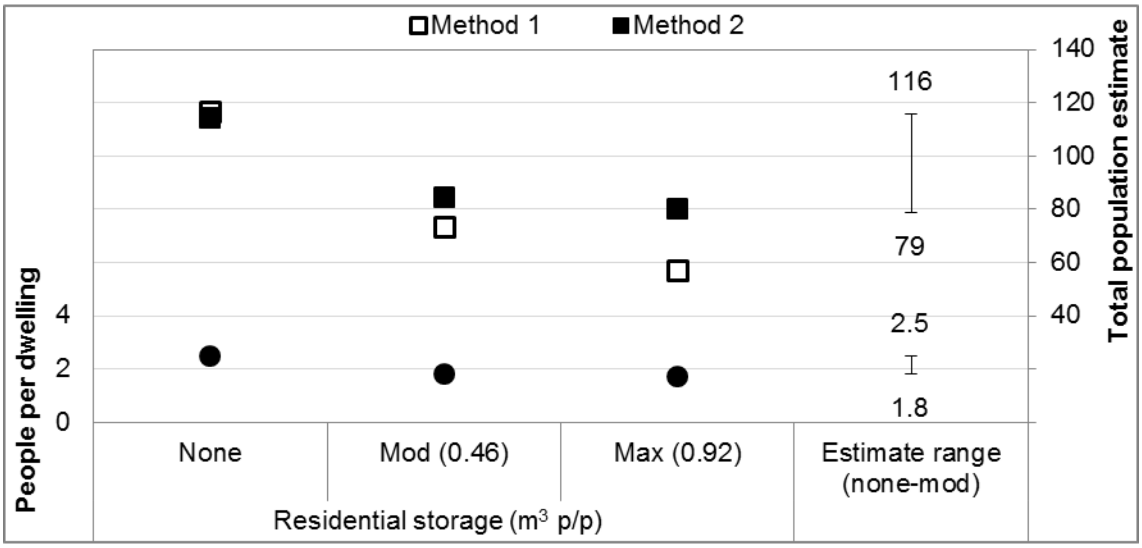


Figure 6.13. SPF population and people per dwelling estimates for Beidha Subphase A2.

Table 6.20. Application of Naroll's (1962) AGF1 to Beidha Subphase A2.

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (115.62)	*Moderate (78.94)*	*Maximum (68.5)*		*None (115.62)*	*Moderate (78.94)*	*Maximum (68.5)*
Total built floor area (m^2)	1184.18	858.81	762.09	595.31			
Built floor area per person (m^2)	10.24	10.88	11.13		5.15	7.54	8.69
RADC (m^2 per person)	6.81	7.24	7.40		2.57	3.76	4.34
Initial growth index	10.91	15.04	16.95				

Table 6.21. Application of Wiessner's (1974) AGF2 to Beidha Subphase A2.

	Initial growth indices		
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (115.62)	*Moderate (78.94)*	*Maximum (68.5)*
Open	0.15	0.32	0.43
Village	17.30	25.34	29.20
Urban	84.26	108.67	119.45

Table 6.22. Population estimates and SPDCs for Beidha Subphase A2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

Data required	
Total site extent (ha)	0.2
Proportion of site assessable (%)	14.68
Number of contemporaneous dwellings in the assessable area	6.75
Dwellings in assessable area	*9*
Contemporaneity value (%)	*75*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	18	30	58.8
Population in the assessable area	*2.64*	*4.40*	*8.63*
People per dwelling in the assessable area	*0.39*	*0.65*	*1.28*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	137.98	-	-	689.88	-	-
RADC	59.41	90.02	167.84	297.07	450.10	839.18
SPF	78.94	-	115.62	394.71	-	578.08

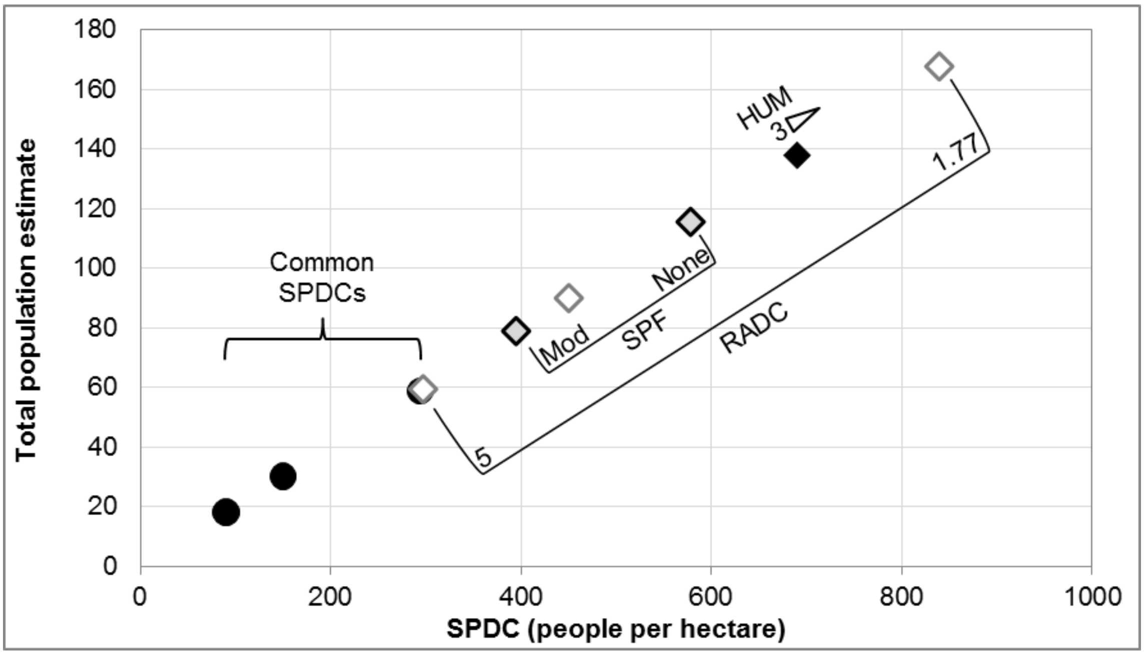


Figure 6.14. Population estimates and SPDCs for Beidha Subphase A2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates. The HUM arrow indicates the direction of estimates if higher nuclear family sizes were employed.

6.3.7 Summary of estimates

Table 6.23. Summary of estimates for Beidha Subphase A2.

Method	Total population	People per dwelling *Based on total number of contemporaneous dwellings:* *45.99*	RADC (m^2/person) *Based on total contemporaneous residential floor area (m^2):* *297.07*	SPDC (people/ha) *Based on total site extent (ha):* *0.2*
HUM	137.98	3	2.15	689.88
RADC	59.41-167.84	1.29-3.65	1.77-5	297.07-839.18
SPF1	78.94-115.62	1.72-2.51	2.57-3.76	394.71-578.08
SPF2[a]	-	1.83-2.49	-	-
AGF1[a]	-	-	6.81-7.24	-
SPDC	18-58.8	0.39-1.28	5.05-16.5	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (115.62)	*Moderate (78.94)*	*Maximum (68.5)*
Naroll's (1962) AGF1		10.91	15.04	16.95
Wiessner's (1974) AGF2	Open settlements	0.15	0.32	0.43
	Village settlements	17.30	25.34	29.20
	Urban settlements	84.26	108.67	119.45

Additional demographic data			
			Contemporaneous (75%)
Proportion (%) of assessable area comprising:	Built area	57.21	42.91
	Residential built area	39.79	29.85
	Built floor area [b]	29.77	22.32
	Residential floor area	19.80	14.85
Proportion (%) of assessable built area comprising:	Residential built area	69.55	
	Built floor area [c]	52.02	
	Residential floor area	34.61	
Proportion (%) of built floor area comprising residential floor area		66.54	
Mean residential floor area of complete dwellings (m^2)		7.26	

[b] Based on assessable area (132.17 m^2) and built floor area (45.23 m^2).
[c] Based on assessable built area (86.77 m^2) and built floor area (45.23 m^2).

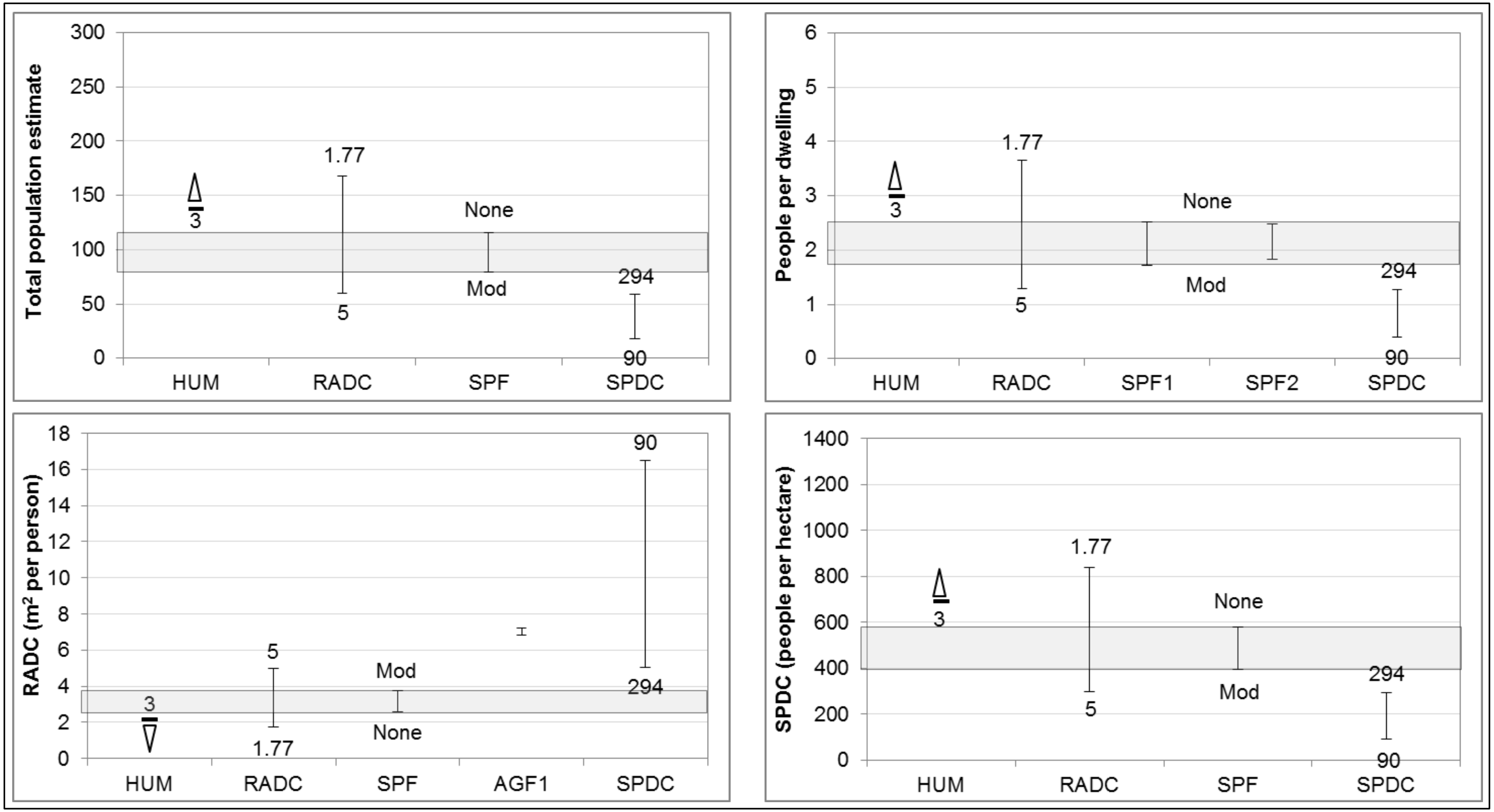


Figure 6.15. Summary of estimates for Beidha Subphase A2. The HUM arrow indicates the direction of estimates if higher nuclear family sizes were employed.

6.4 Population estimates - Subphase B2

6.4.1 Housing unit method

Eight potential dwellings were identified in the assessable area (Table 6.24). The total number of dwellings was estimated at around 27, reduced to around 19 contemporaneous dwellings based on 71.43% structural contemporaneity. Due to the limited mean residential floor area of complete dwellings (6.52 m^2), only the minimum nuclear family size is considered appropriate for this subphase. This produces a population estimate of around 55 people. This low population estimate reflects the low proportions of built area (28.5%) and residential built area (15.14%) within the assessable portion of the site. The proportion of built area is considerably lower than the average proposed by Kuijt (2008a) for MPPNB villages (70%) and the proportion calculated for the preceding phase, which demonstrates comparable architectural and spatial characteristics (Subphase A2 = 57.21%). This is probably due to the destruction of many Phase B buildings, particularly dwellings, by later construction (Byrd 2005a, p.19). To reconstruct a more realistic population estimate for Subphase B2, area proportions derived for Subphase A2 are utilised in place of Subphase B2 area proportions. This produces an estimate of around 50 contemporaneous dwellings and a population estimate of around 150 people (based on the minimum nuclear family size only). Subphase A2 area proportions are utilised for Subphase B2, herein.

6.4.2 Residential area density coefficient

The total residential floor area was estimated at 396.06 m^2. Based on the total contemporaneous residential floor area estimate of 282.91 m^2, the total population was estimated at around 55 to 160 people (Table 6.25).

6.4.3 Storage provisions formulae

Application of the SPF produced population estimates of around 55 people (maximum storage) to 110 people (no storage), and dwelling unit size estimates of around 1.6 people (maximum storage) to 2.2 people (no storage) (Table 6.26; Figure 6.16). Domesticated plant forms emerge during Phase B, suggesting that there may have been an increased amount of storage. However, evidence for storage within structures is generally lacking (i.e. a small pit in Building 31 only). Given this and the small mean floor area of residential structures, it is improbable that the maximum amount of storage would have occurred. Therefore, formulae reflecting limited (none to moderate) residential storage are considered most suitable for Beidha Subphase B2. These formulae produce a population estimate of around 75 to 110 people and a dwelling unit size estimate of around 1.7 to 2.2 people.

6.4.4 Naroll's (1962) allometric growth formula

Naroll's (1962) AGF1 produced total built floor area (A) estimates of around 830 m^2 (moderate storage) to 1,140 m^2 (no storage). Again, these are considerably higher than the built floor area estimated from the archaeological evidence (595.4 m^2) (Table 6.27). Built floor area per person was calculated at 10.31 m^2 (moderate storage) to 11.08 m^2 (no storage), and converted to 6.86 m^2 (moderate storage) to 7.37 m^2 (no storage) residential floor area per person. These RADCs are also considerably higher than those produced from the archaeological evidence (2.56-3.71 m^2 per person). The initial growth index (*a*) was re-calculated at 11.33 (no storage) to 15.48 (moderate storage). This range is considerably lower than Naroll's (1962) original index (*a* = 21.7).

6.4.5 Wiessner's (1974) allometric growth formulae

Wiessner's (1974) AGF2 produced open, village and urban initial growth indices of 0.16 (no storage) to 0.34 (moderate storage); 26.2 to 18.08; and 86.79 to 111.12, respectively (Table 6.28). Due to the continued open layout of the predominantly curvilinear structures; maintenance of external areas for communal food-related practices; and lack of multi-storey structures, the formulae for open and village settlements only are considered suitable for Subphase B2.

6.4.6 Settlement population density coefficient

The commonly utilised SPDCs (90, 150 and 294 people/ha) produced population estimates of 18, 30 and 58.8 people (Table 6.29; Figure 6.17). In the assessable area, this equates to a population of 5.4, nine and 17.64 people, and dwelling unit sizes of 0.36, 0.6 and 1.17 people based on an estimated 15.02 contemporaneous dwellings. Population estimates calculated via micro-level methods produced density estimates of around 750 (HUM), 280 to 800 (RADC), and 380 to 550 (SPDC) people per hectare, respectively. The minimum SPDCs based on the RADC and SPF methods are comparable to the maximum commonly utilised value (294 people/ha). The SPDC based on the HUM far exceeds this value despite based on the minimum nuclear family size (3 people) only.

Table 6.24. HUM population estimates for Beidha Subphase B2.

Based on original area proportions

Method 1: Total potential dwelling number				**26.67**
Number of potential dwellings in the excavated area				8
Assessable area (m^2)				599.92
Estimated total site extent (m^2)				2000
Assessable area (proportion)				0.3
Method 2: Total potential dwelling number				**26.67**
Mean potential residential built area (m^2)				11.35
Potential residential built area (m^2)	*Building 25*	*11.97*	*Building 47*	*10.47*
	Building 34	*10.92*	*Building 60*	*12.72*
	Building 36	*14.71*	*Building 61*	*14.25*
	Building 44	*4.01*	*Building 82*	*11.77*
Total built area estimate (m^2)				570.01
Assessable area (m^2)				*599.92*
Assessable built area (m^2)				*170.98*
Assessable built area as a proportion of assessable area				*0.285*
Estimated total site extent (m^2)				*2000*
Residential built area as a proportion of assessable built area				0.5312
Potential residential built area (m^2)				*90.82*
Total potential residential built area (m^2)				302.77
Method 3: Total potential dwelling number				**26.67**
Potential residential built area as a proportion of assessable area				0.1514
Total number of contemporaneous dwellings (71.43%)				19.05
Total population estimate based on nuclear family size:	**Minimum**	**3**		**57.15**
	Average	**5.5**		**104.78**
	Maximum	**8**		**152.4**

Based on Subphase A2 area proportions (highlighted in grey)

Method 2: Total potential dwelling number			**70.1**
Total built area estimate (m^2)			1144.18
Assessable built area as a proportion of assessable area			*0.5721*
Residential built area as a proportion of assessable built area			0.6955
Total potential residential built area (m^2)			795.82
Method 3: Total potential dwelling number			**70.1**
Potential residential built area as a proportion of assessable area			0.3979
Total number of contemporaneous dwellings (71.43%)			50.07
Total population estimate based on nuclear family size:	**Minimum**	**3**	**150.22**
	Average	**5.5**	**275.4**
	Maximum	**8**	**400.58**

Table 6.25. RADC population estimates for Beidha Subphase B2 based on Subphase A2 area proportions (highlighted in grey).

Method 2: Total potential residential floor area (m^2)				**396.06**
Total built area estimate (m^2)				1144.14
			Assessable area (m^2)	*599.92*
			Assessable built area (m^2)	*170.98*
			Assessable built area as a proportion of assessable area	*0.5721*
			Estimated total site extent (m^2)	*2000*
Potential residential floor area as a proportion of assessable built area				0.3462
Potential residential floor area (m^2)				*49.82*
Potential residential floor area (m^2)	*Building 25*	*7.69*	*Building 47*	*6.29*
	Building 34	*5.84*	*Building 60*	*6.02*
	Building 36	*6.74*	*Building 61*	*9.17*
	Building 44	*2.25*	*Building 82*	*5.82*
Method 3: Total potential residential floor area (m^2)				**396.06**
Potential residential floor area as a proportion of assessable area				0.1980
Total contemporaneous residential floor area (m^2) (71.43%)				282.91
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**		**159.83**
	Average	**3.3**		**85.73**
	Maximum	**5**		**56.58**

Table 6.26. SPF population and people per dwelling estimates for Beidha Subphase B2.

	Storage provisions formulae (m^3 residential storage per person)		
	None	*Moderate (0.46)*	*Maximum (2 x 0.46)*
Method 1: Total population (P) based on total contemporaneous residential floor area (282.91 m^2)			
Total population (P)	111.20	70.11	54.23
Method 2: People per dwelling (P) based on mean residential floor area of complete dwellings (6.52 m^2) and total population based on total number of contemporaneous dwellings (50.07)			
People per dwelling (P)	2.20	1.65	1.60
Total population	109.98	82.57	80.12
Mean total population	**110.59**	**76.34**	**67.18**

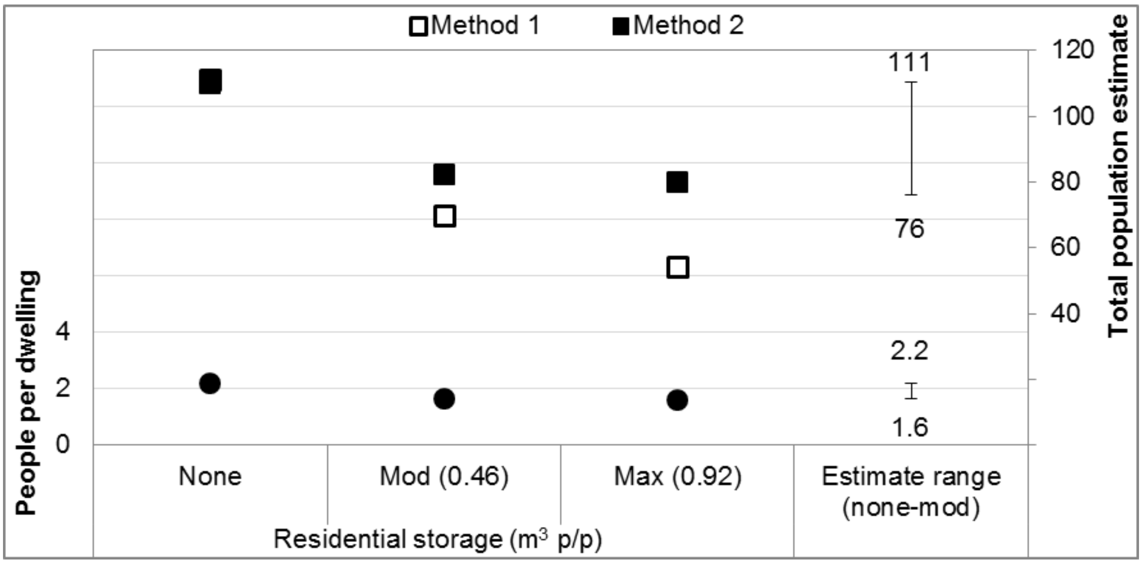


Figure 6.16. SPF population and people per dwelling estimates for Beidha Subphase B2.

Table 6.27. Application of Naroll's (1962) AGF1 to Beidha Subphase B2.

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (110.59)	*Moderate (76.34)*	*Maximum (67.18)*		*None (110.59)*	*Moderate (76.34)*	*Maximum (67.18)*
Total built floor area (m^2)	1140.72	834.89	749.70	595.40			
Built floor area per person (m^2)	10.31	10.94	11.16		5.38	7.80	8.86
RADC (m^2 per person)	6.86	7.28	7.42		2.56	3.71	4.21
Initial growth index	11.33	15.48	17.23				

Table 6.28. Application of Wiessner's (1974) AGF2 to Beidha Subphase B2.

	Initial growth indices		
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (110.59)	*Moderate (76.34)*	*Maximum (67.18)*
Open	0.16	0.34	0.44
Village	18.08	26.20	29.77
Urban	86.79	111.12	121.01

Table 6.29. Population estimates and SPDCs for Beidha Subphase B2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

Data required	
Total site extent (ha)	0.2
Proportion of site assessable (%)	30.00
Number of contemporaneous dwellings in the assessable area	15.02
Total number of contemporaneous dwellings (derived from HUM)	*50.07*
Proportion of site assessable (%)	*30*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	18	30	58.8
Population in the assessable area	*5.40*	*9.00*	*17.64*
People per dwelling in the assessable area	*0.36*	*0.60*	*1.17*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	150.22	-	-	751.10	-	-
RADC	56.58	85.73	159.83	282.91	428.64	799.17
SPF	76.34	-	110.59	381.69	-	552.97

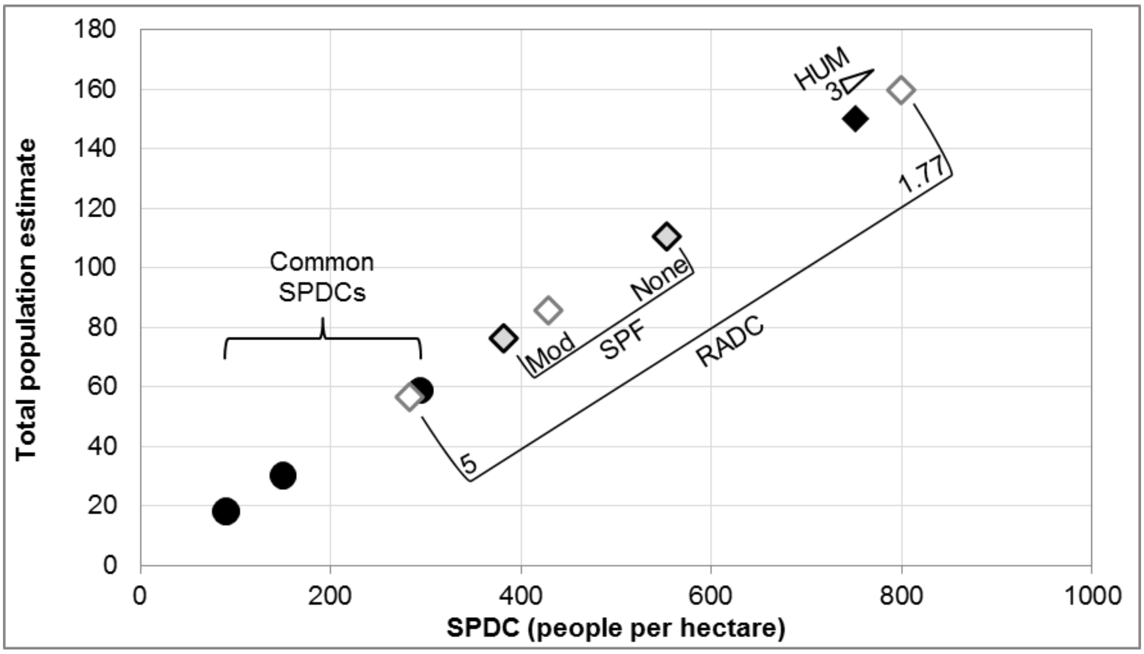


Figure 6.17. Population estimates and SPDCs for Beidha Subphase B2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

6.4.7 Summary of estimates

Table 6.30. Summary of estimates for Beidha Subphase B2.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 50.07	*Based on total contemporaneous residential floor area (m^2): 282.91*	*Based on total site extent (ha): 0.2*
HUM	150.22	3	2.15	751.1
RADC	56.58-159.83	1.13-3.19	1.77-5	282.91-799.17
SPF1	76.34-110.59	1.52-2.21	2.56-3.71	381.69-552.97
SPF2[a]	-	1.65-2.2	-	-
AGF1[a]	-	-	6.86-7.28	-
SPDC	18-58.8	0.36-1.17	4.81-15.72	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage:		
		None (110.59)	*Moderate (76.34)*	*Maximum (67.18)*
Naroll's (1962) AGF1		11.33	15.48	17.23
Wiessner's (1974) AGF2	Open settlements	0.16	0.34	0.44
	Village settlements	18.08	26.20	29.77
	Urban settlements	86.79	111.12	121.01

Additional demographic data			
			Contemporaneous (71.43%)
Proportion (%) of assessable area comprising:	Built area	57.21	40.87
	Residential built area	39.79	28.42
	Built floor area[b]	29.77	21.26
	Residential floor area	19.80	14.14
Proportion (%) of built floor area comprising residential floor area		66.52	
Mean residential floor area of complete dwellings (m^2)		6.52	

[b] Proportions derived from Subphase A2; converted based on Subphase B2 contemporaneity value.

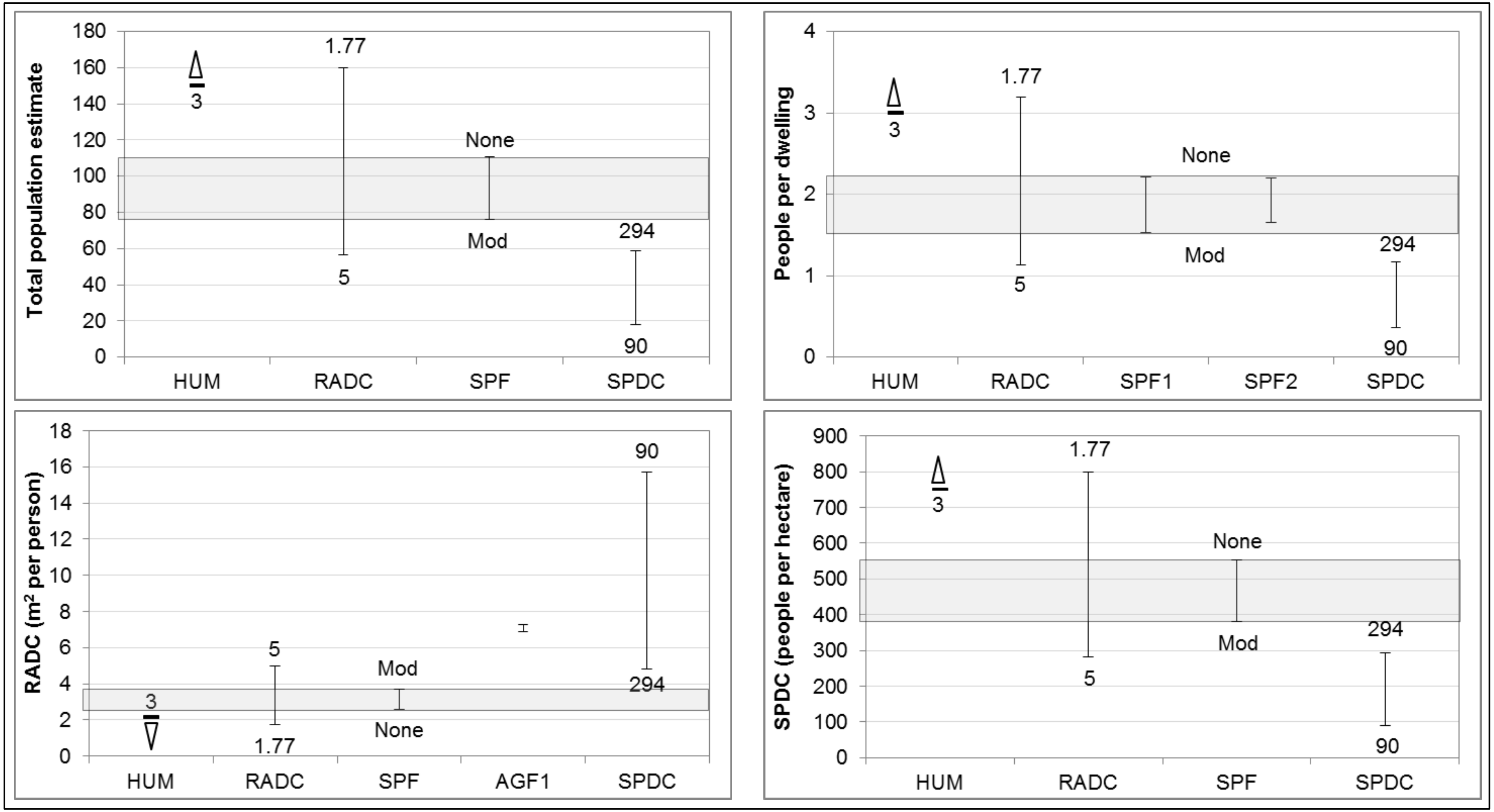


Figure 6.18. Summary of estimates for Beidha Subphase B2.

6.5 Population estimates - Subphase C2

6.5.1 Housing unit method

The total number of dwellings was estimated at around 47, reduced to around 37 contemporaneous dwellings based on 77.78% structural contemporaneity (Table 6.31). The large mean residential floor area of complete dwellings (17.15 m^2) could have accommodated any of the nuclear family sizes employed in this investigation. These produce a total population estimate of around 110 to 290 people.

6.5.2 Residential area density coefficient

Upper storeys of dwellings are considered to represent residential area in Phase C. The method for calculating upper storey residential floor area is outlined in Section 5.2.2. The total residential floor area was estimated at around 650 m^2 (Table 6.32). Based on the total contemporaneous residential floor area estimate of 500 m^2, the total population was estimated at around 100 to 285 people.

6.5.3 Storage provisions formulae

Application of the SPF produced population estimates of around 95 people (maximum storage) to 235 people (no storage) and dwelling unit size estimates of around 3.6 people (maximum storage) to 6.4 people (no storage) (Table 6.33; Figure 6.19).

Given the considerable storage space available on ground floors, it is improbable that the maximum amount of storage occurred within the upper storey residential area. Upper storey residential area measurements incorporate some degree of adjustment for storage based on upper storey storage evidence in Building 73 and blocked walls in several basements interpreted as representing similar storage facilities. As such, the formulae based on limited (none to moderate) residential storage only are considered suitable for Subphase C2. These produced population estimates of around 140 to 215 people and dwelling unit size estimates of around 4.3 to 6.4 people.

6.5.4 Naroll's (1962) allometric growth formula

Naroll's (1962) AGF1 based on the applicable SPF population estimates produced total built floor area (A) estimates of around 1,400 m^2 (moderate storage) to 2,000 m^2 (no storage). The built floor area estimate derived from the archaeological evidence

(1,490.16 m^2) falls within this range (Table 6.34). Built floor area per person was calculated at 9.28 m^2 (no storage) to 9.93 m^2 (moderate storage). These are closely comparable to Naroll's (1962) constant of 10 m^2 built floor area per person. These values were converted to 4.03 m^2 (no storage) to 4.31 m^2 (moderate storage). These are marginally higher than RADCs derived from the archaeological evidence (2.33-3.58 m^2 per person).

The initial growth index (*a*) was re-calculated at 16.15 (no storage) to 23.16 (moderate storage). Naroll's (1962) original index (*a* = 21.7) falls within this range.

6.5.5 Wiessner's (1974) allometric growth formulae

Wiessner's (1974) AGF2 based on the applicable SPF population estimates produced open, village and urban initial growth indices of 0.06 (no storage) to 0.15 (moderate storage); 13.9 to 21.34; and 83.38 to 110.95, respectively (Table 6.35). The presence of two-storey, agglomerated, rectilinear architecture indicates that the formula for open settlements is not suitable for Subphase C2.

6.5.6 Settlement population density coefficient

The commonly utilised SPDCs (90, 150 and 294 people/ha) produced total population estimates of 27, 45 and 88.2 people (Table 6.36; Figure 6.20). In the assessable area, this equates to a population of 8.62, 14.36 and 28.15, and dwelling unit sizes of 0.74, 1.23 and 2.41 people based on an estimated 11.67 contemporaneous dwellings.

Population estimates calculated via micro-level methods produced density estimates of around 370 to 970 (HUM), 340 to 950 (RADC), and 470 to 720 (SPDC) people per hectare, respectively. The SPDCs derived from HUM, RADC and SPF population estimates demonstrate considerable overlap, and all exceed the maximum commonly utilised value (294 people/ha).

Table 6.31. HUM population estimates for Beidha Subphase C2.

Method 1: Total potential dwelling number					**46.99**
Number of potential dwellings in the excavated area					15
Assessable area (m^2)					957.64
Estimated total site extent (m^2)					3000
Assessable area (proportion)					0.3192
Method 2: Total potential dwelling number					**46.99**
Mean potential residential built area (m^2)					22.84
Potential residential built area (m^2)	*Building 1*	*13.08*	*Building 14*		*21.54*
	Building 2	*39.91*	*Building 19*		*33.17*
	Building 3	*32.75*	*Building 71*		*8.63*
	Building 4	*29.11*	*Building 72*		*15.90*
	Building 5	*23.57*	*Building 73*		*21.64*
	Building 10	*29.92*	*West of 14*		*10.07*
	Building 12	*25.17*	*West of 19*		*7.57*
	Building 13	*30.62*			
Total built area estimate (m^2)					1780.47
				Assessable area (m^2)	*957.64*
				Assessable built area (m^2)	*568.35*
				Assessable built area as a proportion of assessable area	*0.5935*
				Estimated total site extent (m^2)	*3000*
Residential built area as a proportion of assessable built area					0.6029
				Potential residential built area (m^2)	*342.65*
Total potential residential built area (m^2)					1073.42
Method 3: Total potential dwelling number					**46.99**
Potential residential built area as a proportion of assessable area					0.3578
Total number of contemporaneous dwellings (77.78%)					36.55
Total population estimate based on nuclear family size:	**Minimum**	**3**			**109.65**
	Average	**5.5**			**201.02**
	Maximum	**8**			**292.39**

Table 6.32. RADC population estimates for Beidha Subphase C2.

Method 1: Total potential residential floor area (m^2)					**646.75**
Potential residential floor area (m^2)					206.45
Potential residential floor area (m^2)	*Building 1*	*8.76*	*Building 14*		*13.48*
	Building 2	*25.42*	*Building 19*		*21.41*
	Building 3	*18.39*	*Building 71*		*5.21*
	Building 4	*10.84*	*Building 72*		*10.61*
	Building 5	*13.98*	*Building 73*		*12.02*
	Building 10	*18.99*	*West of 14*		*5.91*
	Building 12	*16.03*	*West of 19*		*4.42*
	Building 13	*20.98*			
Assessable area (m^2)					957.64
Estimated total site extent (m^2)					3000
Assessable area (proportion)					0.3192
Method 2: Total potential residential floor area (m^2)					**646.75**
Total built area estimate (m^2)					1780.47
				Assessable area (m^2)	*957.64*
				Assessable built area (m^2)	*568.35*
				Assessable built area as a proportion of assessable area	*0.5935*
				Estimated total site extent (m^2)	*3000*
Potential residential floor area as a proportion of assessable built area					0.3632
				Potential residential floor area (m^2)	*206.45*
Method 3: Total potential residential floor area (m^2)					**646.75**
Potential residential floor area as a proportion of assessable area					0.2156
Total contemporaneous residential floor area (m^2) (77.78%)					503.04
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**			**284.20**
	Average	**3.3**			**152.44**
	Maximum	**5**			**100.61**

Table 6.33. SPF population and people per dwelling estimates for Beidha Subphase C2.

	Storage provisions formulae (m^3 residential storage per person)		
	None	*Moderate (0.46)*	*Maximum (2 x 0.46)*
Method 1: Total population (P) based on total contemporaneous residential floor area (503.04 m^2)			
Total population (P)	198.02	124.64	96.13
Method 2: People per dwelling (P) based on mean residential floor area of complete dwellings (17.15 m^2) and total population based on total number of contemporaneous dwellings (36.55)			
People per dwelling (P)	6.39	4.28	3.62
Total population	233.51	156.50	132.42
Mean total population	**215.77**	**140.57**	**114.27**

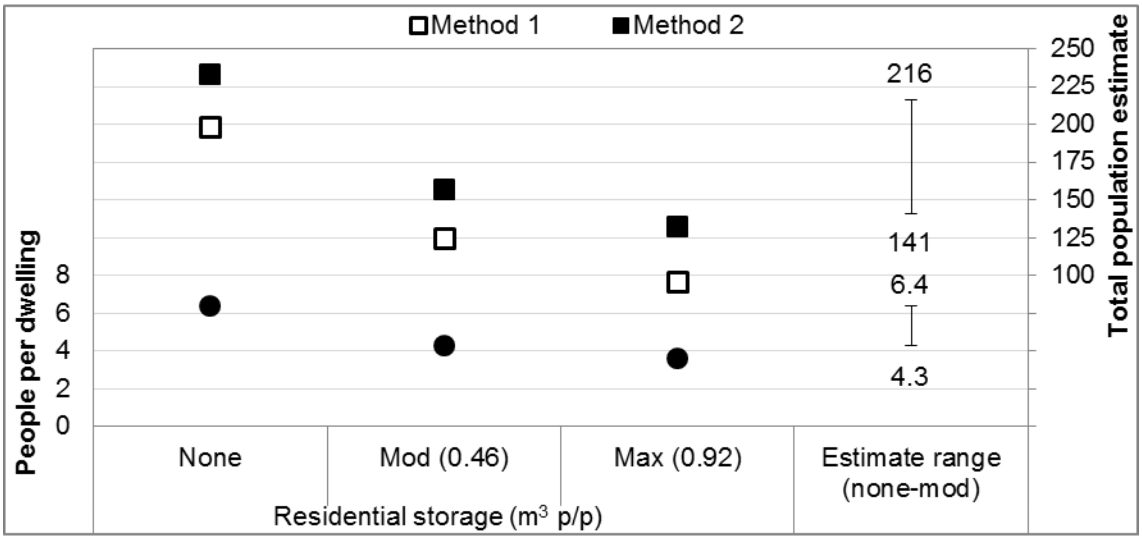


Figure 6.19. SPF population and people per dwelling estimates for Beidha Subphase C2.

Table 6.34. Application of Naroll's (1962) AGF1 to Beidha Subphase C2.

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (215.77)	*Moderate (140.57)*	*Maximum (114.27)*		*None (215.77)*	*Moderate (140.57)*	*Maximum (114.27)*
Total built floor area (m^2)	2002.44	1395.97	1172.57	1490.10			
Built floor area per person (m^2)	9.28	9.93	10.26		6.91	10.60	13.04
RADC (m^2 per person)	4.03	4.31	4.45		2.33	3.58	4.40
Initial growth index	16.15	23.16	27.58				

Table 6.35. Application of Wiessner's (1974) AGF2 to Beidha Subphase C2.

	Initial growth indices		
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (215.77)	*Moderate (140.57)*	*Maximum (114.27)*
Open	0.06	0.15	0.23
Village	13.90	21.34	26.25
Urban	83.38	110.95	127.38

Table 6.36. Population estimates and SPDCs for Beidha Subphase C2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

Data required	
Total site extent (ha)	0.3
Proportion of site assessable (%)	31.92
Number of contemporaneous dwellings in the assessable area	11.67
Dwellings in assessable area	*15*
Contemporaneity value (%)	*77.78*

Method 1: Total population based on commonly utilised SPDCs

	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	27	45	88.2
Population in the assessable area	*8.62*	*14.36*	*28.15*
People per dwelling in the assessable area	*0.74*	*1.23*	*2.41*

Method 2: SPDCs based on HUM, RADC and SPF population estimates

Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	109.65	201.02	292.39	365.49	670.07	974.65
RADC	100.61	152.44	284.20	335.36	508.12	947.34
SPF	140.57	-	215.77	468.56	-	719.23

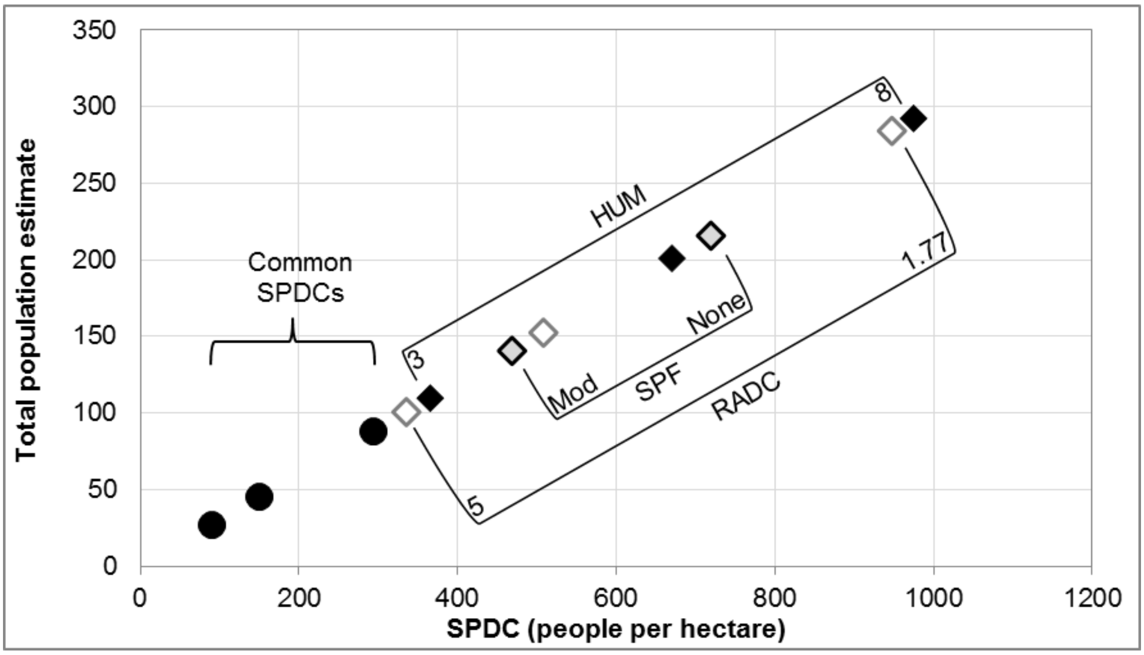


Figure 6.20. Population estimates and SPDCs for Beidha Subphase C2 derived from commonly utilised SPDCs and HUM, RADC and SPF population estimates.

6.5.7 Summary of estimates

Table 6.37. Summary of estimates for Beidha Subphase C2.

Method	Total population	People per dwelling *Based on total number of contemporaneous dwellings:* *36.55*	RADC (m^2/person) *Based on total contemporaneous residential floor area (m^2):* *503.04*	SPDC (people/ha) *Based on total site extent (ha):* *0.3*
HUM	109.65-292.39	3-8	1.72-4.59	365.49-974.65
RADC	100.61-284.2	2.75-7.78	1.77-5	335.36-947.34
SPF1	140.57-215.77	3.85-5.9	2.33-3.58	468.56-719.23
SPF2[a]	-	4.28-6.39	-	-
AGF1[a]	-	-	4.03-4.31	-
SPDC	27-88.2	0.74-2.41	5.7-18.63	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage: *None (215.77)*	*Moderate (140.57)*	*Maximum (114.27)*
Naroll's (1962) AGF1		16.15	23.16	27.58
Wiessner's (1974) AGF2	Open settlements	0.06	0.15	0.23
	Village settlements	13.90	21.34	26.25
	Urban settlements	83.38	110.95	127.38

Additional demographic data			*Contemporaneous (77.78%)*
Proportion (%) of assessable area comprising:	Built area	59.35	46.16
	Residential built area	35.78	27.83
	Built floor area [b]	49.67	38.63
	Residential floor area	21.56	16.77
Proportion (%) of assessable built area comprising:	Residential built area	60.29	
	Built floor area [c]	83.69	
	Residential floor area	36.32	
Proportion (%) of built floor area comprising residential floor area		43.40	
Mean residential floor area of complete dwellings (m^2)		17.15	

[b] Based on assessable area (957.64 m^2) and built floor area (475.66 m^2).
[c] Based on assessable built area (568.35 m^2) and built floor area (475.66 m^2).

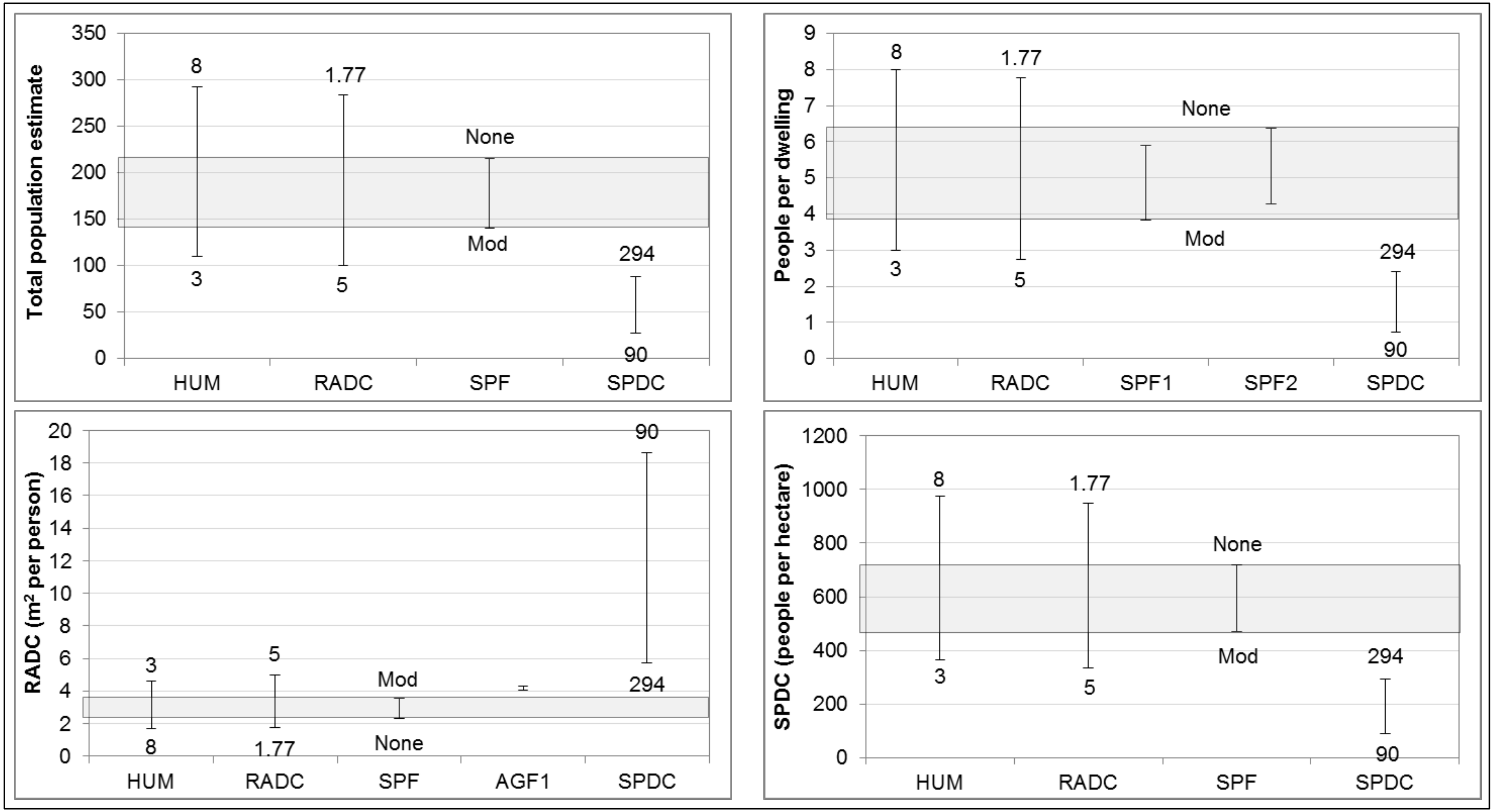


Figure 6.21. Summary of estimates for Beidha Subphase C2.

6.6 Analysis of methods and results

6.6.1 Housing unit method (HUM)

The HUM is considered a suitable method for estimating the population of PPN villages and for providing further demographic data. However, issues arise from the application of a predetermined range of dwelling occupant numbers. In this investigation, the assumption of nuclear family dwelling units was tested via application of dwelling unit sizes of three to eight people. This produces large population estimate ranges, except where insufficient mean residential floor area allows exclusion of one or more of these family sizes, as was the case for Subphases A2 (7.26 m^2) and B2 (6.52 m^2) (Table 6.38).

The HUM produced some interesting data for comparison. The results indicate a total of around 22 contemporaneous dwellings during Subphase A1 and more than twice this during Subphases A2 (c. 46) and B2 (c. 50). Interestingly, despite a significantly higher population estimate in Subphase C2, there appears to be a decrease in the number of contemporaneous dwellings (c. 37). This may reflect affordance of higher dwelling unit sizes within the larger, two-storey, highly compartmentalised Subphase C2 residential structures (Byrd 2005a; Rollefson and Kafafi 2013).

Another interesting set of data relates to the proportions of built area and residential built area in the assessable area. The proportion of built area appears to have remained relatively consistent throughout (around 60%), except for Subphase B2 (28.5%) where later construction had destroyed much of the archaeological evidence. Proportions for Subphases A1 (c. 66%) and A2 (c. 57%) coincide with the lower range of Kuijt's (2008) average estimates for the proportion of built area in MPPNB villages (60-80%). The Subphase C2 proportion (c. 59%) is around 20% lower than that proposed by Kuijt (2008a) for LPPNB settlements (80-88%), though it should be noted that Kuijt classified this subphase as MPPNB.

The proportion of potential residential built area in assessable built area demonstrates greater variation. A higher proportion during Subphase A1 (c. 86%) reflects a lack of differentiation between residential and non-residential built area; whilst lower proportions, particularly in Subphase C2 (c. 60%), reflect increasing designation of built space for non-residential purposes. This changing use of space is similarly evidenced in the proportion of residential built area in assessable area, which decreased from around 57% in Subphase A1 to around 36% by Subphase C2.

Table 6.38. HUM results for Beidha Subphases A1 to C2.

		Subphase			
		A1	*A2*	*B2*	*C2*
Population estimate		64.85-172.94	137.98	150.22	109.65-292.39
Nuclear family sizes applied		3-8	3	3	3-8
Mean residential floor area of complete dwellings (m^2)		11.56	7.26	6.52	17.15
Total number of contemporaneous dwellings		21.62	45.99	50.07	36.55
Area proportions (%)	Built area in assessable area	65.65	57.21	28.5*	59.35
	Residential built area in assessable area	56.63	39.79	15.14*	35.78
	Residential built area in assessable built area	86.26	69.55	53.12*	60.29

* Distorted by later construction; proportions for Subphase A2 used in estimates.

6.6.2 Residential area density coefficient method (RADC)

The RADC method is also considered suitable for estimating the population of PPN villages and for providing further demographic data. However, it is necessary to identify appropriate RADCs for specific settlement types as space requirements per person are impacted by various factors (i.e. available space, notions of privacy, permanence of settlement, etc.). Furthermore, the RADCs must be derived from living or sleeping area only.

Beneficial demographic data produced by the RADC method includes estimates of total contemporaneous residential floor area and area proportions (Table 6.39). The results indicate a total of around 210 m^2 contemporaneous residential floor area during Subphase A1, increasing to around 290 m^2 during Subphases A2 and B2. This increase reflects a substantial increase in the number of dwellings rather than increases in the residential floor area of individual dwellings. The results indicate a considerable increase in total contemporaneous residential floor area by Subphase C2 (c. 505 m^2), reflecting the greater amount of residential floor area within the two-storey structures (Byrd 2005a)

The proportions of residential floor area in assessable area and assessable built area were highest in Subphase A1 (c. 30% and 45%), and slightly lower in Subphases A2 (c. 20% and 35%) and C2 (c. 22% and 36%). This reflects the increasing designation of built floor area for non-residential activities (Byrd 2005a). Lower proportions in Subphase A2 (and probably B2) also reflect the smaller dimensions of dwellings.

Table 6.39. RADC method results for Beidha Subphases A1 to C2.

		Subphase		
	A1	*A2*	*B2*	*C2*
Population estimate	41.98-118.6	59.41-167.84	56.58-159.83	100.61-284.2
RADCs (m^2 per person) applied	1.77-5			
People per dwelling range based on RADC	1.94-5.49	1.29-3.65	1.13-3.19	2.75-7.78
Total contemporaneous residential floor area (m^2)	209.92	297.07	282.91	503.04
Area proportions (%): Residential floor area in assessable area	29.39	19.8	8.3*	21.56
Area proportions (%): Residential floor area in assessable built area	44.76	34.61	29.14*	36.32

* Distorted by later construction; proportions for Subphase A2 used in estimates.

6.6.3 Storage provisions formulae (SPF)

The SPF is considered the most robust, valid and beneficial method in this investigation for several reasons (see Section 10.2.1). The SPF was applied for three purposes: to estimate population (Method 1 and 2); to estimate the number of people per dwelling (Method 2); and to determine the probable amount of storage within the residential floor area. Archaeological evidence indicated limited (none to moderate) storage provisions within the residential floor area throughout the PPN occupation at Beidha. Application of selected formulae produced reasonably confined estimate ranges compared to other methods (Table 6.40; Figure 6.22).

A comparison of SPF population and dwelling unit size estimates with estimates of available residential floor area can confirm the potential amount of storage provisions. For example, during Subphase C2, dwellings comprised two-storey structures with large residential floor areas (mean c. 17 m^2). It is improbable that these dwellings were occupied by less than four people on average. This potentially supports the exclusion of the maximum SPF for Subphase C2. However, as SPF estimates are based on adult population size, consideration of children would increase the population estimate.

Assessment of theorised group size thresholds and estimates for preceding subphases may also lead to the exclusion of specific formulae. For example, by Subphase B2, a sedentary community appears to have existed in this location for at least 200 years and evidence suggests that the community engaged in agricultural practices relating to domesticated plants. It is almost certain that the population had exceeded (i) 25 people, which is the minimum hypothesised threshold for transition to sedentary society; and (ii) the minimum population estimate for the preceding subphase (c. 74 people). The population may even have exceeded 100 people, which is the hypothesised threshold at which communities adopt agricultural practices (Fletcher 1981). Therefore, it could be suggested that the maximum (or even the moderate) amount of storage did not occur during Subphase B2 because the resulting population estimate may be too low (c. 55-80 people).

Table 6.40. SPF results for Beidha Subphases A1 to C2.

	Storage Provisions	Subphase *A1*	*A2*	*B2*	*C2*
Method 1					
Total contemporaneous residential floor area (m^2)		209.92	297.07	282.91	503.04
Total population	None	82.42	116.79	111.20	198.02
	Mod (0.46)	52.03	73.62	70.11	124.64
	Max (2×0.46^3)	40.35	56.93	54.23	96.13
Method 2					
Mean residential floor area of complete dwellings (m^2)		11.56	7.26	6.52	17.15
People per dwelling	None	4.18	2.49	2.20	6.39
	Mod (0.46)	2.90	1.83	1.65	4.28
	Max (2×0.46^3)	2.56	1.74	1.60	3.62
Total population	None	90.45	114.44	109.98	233.51
	Mod (0.46)	62.63	84.27	82.57	156.50
	Max (2×0.46^3)	55.32	80.07	80.12	132.42
		Estimates based on selected formulae (none-moderate)			
Total population*		57-86	79-116	76-111	141-216
People per dwelling		2.9-4.2	1.8-2.5	1.7-2.2	4.3-6.4

* Based on mean of the two methods.

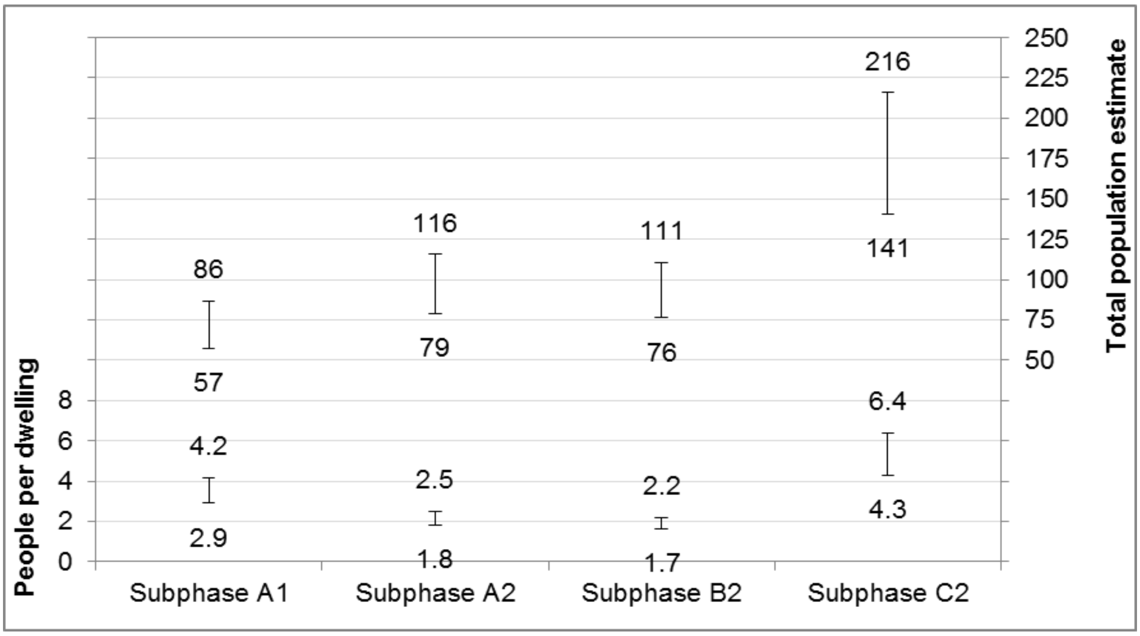


Figure 6.22. Estimates of people per dwelling (left axis) and total population (right axis) derived from applicable SPF for Beidha Subphases A1 to C2 (all subphases: none to moderate storage).

6.6.4 Allometric growth formulae (AGF)

Naroll's (1962) AGF1

Naroll's (1962) AGF1 ($A = 2.17 \times P^{0.84195}$) was applied to calculate total built floor area (A), built floor area per person and residential floor area per person (RADC), using the SPF population estimates as the P variable (Table 6.41; Figure 6.23). Across all phases, estimates of built floor area per person (c. 9.3-11.4 m^2) were closely comparable to Naroll's (1962) suggested constant of 10 m^2. This could support the functionality of Naroll's (1962) formula and the accuracy of the SPF population estimates produced in this investigation.

However, a comparison of estimates of total built floor area, built floor area per person and RADC derived from Naroll's (1962) AGF1 and the excavated evidence suggest that Naroll's (1962) AGF1 is not suitable for estimating population parameters of all phases at Beidha. Estimates based on the AGF1 were considerably higher than those based on the excavated evidence for Subphases A1, A2 and B2, though comparable for Subphase C2. In addition, re-calculated initial growth indices were considerably lower than the original index (a = 21.7) for Subphases A1, A2 and B2, though comparable for Subphase C2.

Naroll's (1962) formula was originally derived from predominantly larger settlements comprising agglomerated, rectilinear structures, similar to the Phase C occupation evidence. The comparability between estimates derived from the AGF1 and those derived from the excavated evidence for Subphase C2, indicates that Naroll's (1962) formula may be suitable for estimating demographic parameters of villages with agglomerated rectilinear architecture only.

The comparability between the re-calculated initial growth indices derived for Subphases A1, A2 and B2 (mean c. 10-14) indicates that a lower initial growth index may be more appropriate when applying Naroll's (1962) AGF1 to villages of this type (i.e. with curvilinear architecture).

Table 6.41. Naroll's (1962) AGF1 (A = 2.17 x $P^{0.84195}$) results for Beidha Subphases A1 to C2.

	Subphase			
	A1	*A2*	*B2*	*C2*
Method 1: Calculations based on Naroll's (1962) formula and suitable SPF population estimates (P): A = 21.7 x $P^{0.84195}$				
Total built floor area (m^2) (A)	656.06-926.96	834.89-1140.72	834.89-1140.72	1395.97-2002.44
Built floor area per person (m^2)	10.72-11.44	10.31-10.94	10.31-10.94	9.28-9.93
RADC (m^2 per person)	9.21-9.83	6.86-7.28	6.86-7.28	4.03-4.31
Proportion of residential floor area in built floor area (%)	*85.88*	*66.54*	*66.52**	*43.4*
Calculations based on mean of suitable SPF population estimate and archaeological evidence				
SPF population estimates (all none to moderate storage)	*57.33-86.44*	*78.94-115.62*	*76.34-110.59*	*140.57-215.77*
Built floor area per person (m^2)	3.96-5.97	5.15-7.54	5.38-7.8	6.91-10.6
Estimated total built floor area (m^2)	*342.21*	*595.31*	*595.4*	*1490.1*
RADC range (m^2 per person)	2.43-3.66	2.57-3.76	2.56-3.71	2.33-3.58
Estimated total contemporaneous residential floor area (m^2)	209.92	297.07	282.91	503.04
Method 2: Re-calculated initial growth indices (*a*) based on estimated total built floor area (A) and SPF population estimate (P)				
Initial growth index (a)	8.01-11.32	10.91-15.04	11.33-15.48	16.15-23.16

* Based on Subphase A2 proportions.

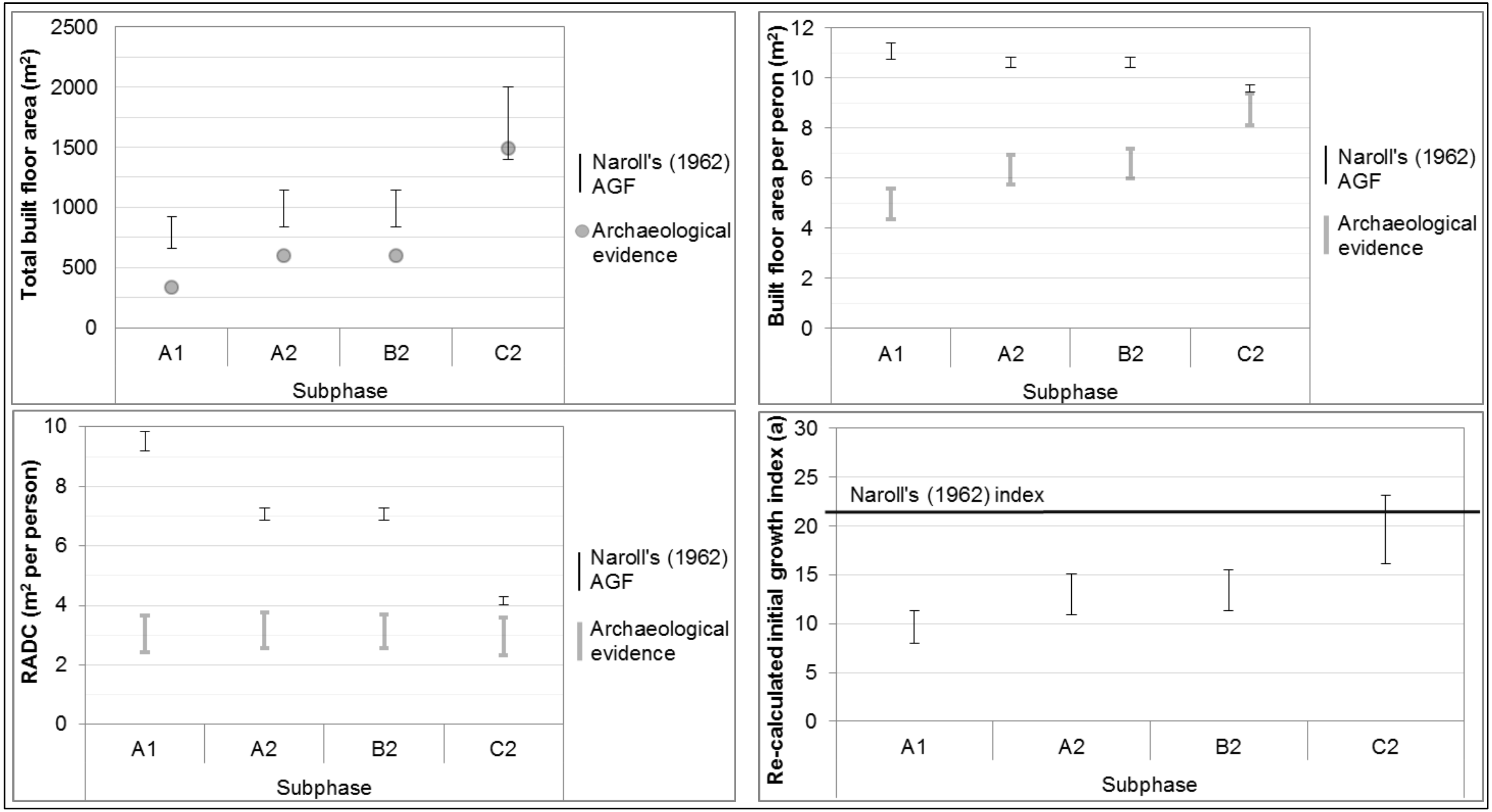


Figure 6.23. Naroll's (1962) AGF1 ($A = 2.17 \times P^{0.84195}$) results for Beidha Subphases A1 to C2 compared to data derived from the archaeological evidence.

Wiessner's (1974) AGF2

Wiessner's (1974) AGF2 were applied to calculate initial growth indices for open, village and urban settlements (Table 6.42; Figure 6.24). All phases represent village settlements, with Subphases A1, A2 and B2 also considered open settlements, and Subphase C2 also considered an urban settlement.

Initial growth indices derived for open settlements (Subphases A1, A2 and B2) were almost equivalent (min: 0.13-0.16; max: 0.3-0.34). Indices derived for village settlements (all subphases) demonstrated a limited range, with a minimum of around 12 to 18 and a maximum of around 17 to 26. Only Subphase C2 was classified as a potential urban settlement and, therefore, no comparisons can be made regarding the urban initial growth index.

There is generally a disparity between settlement type-based initial growth indices for settlements identified as that particular settlement type and those which are not. For example, the open index derived for Subphase C2 (a village/urban settlement) was notably lower than those derived for settlements identified as open settlements (Subphases A1, A2 and B2); and the urban index derived for Subphase A1 (an open/village settlement) is notably lower than that derived for Subphase C2. However, there is no distinction between the urban indices derived for Subphase C2 and Subphases A2 and B2, which were not identified as potential urban settlements. This analysis highlights the potential for construction of specific initial growth indices for Wiessner's (1974) AGF2 for open and village settlements, though not necessarily for urban settlements.

Table 6.42. Wiessner's (1974) AGF2 results for Beidha Subphases A1 to C2.

Initial growth indices for:	**Subphase**			
	A1	*A2*	*B2*	*C2*
Open settlements	0.13-0.3	0.15-0.32	0.16-0.34	0.06-0.15
Village settlements	11.57-17.44	17.3-25.34	18.08-26.2	13.9-21.34
Urban settlements	51.15-67.25	84.26-108.67	86.79-111.12	83.38-110.95
Site extent (m^2)	*1000*	*2000*	*2000*	*3000*
SPF population estimates (none to moderate storage)	*57.33-86.44*	*78.94-115.62*	*76.34-110.59*	*140.57-215.77*

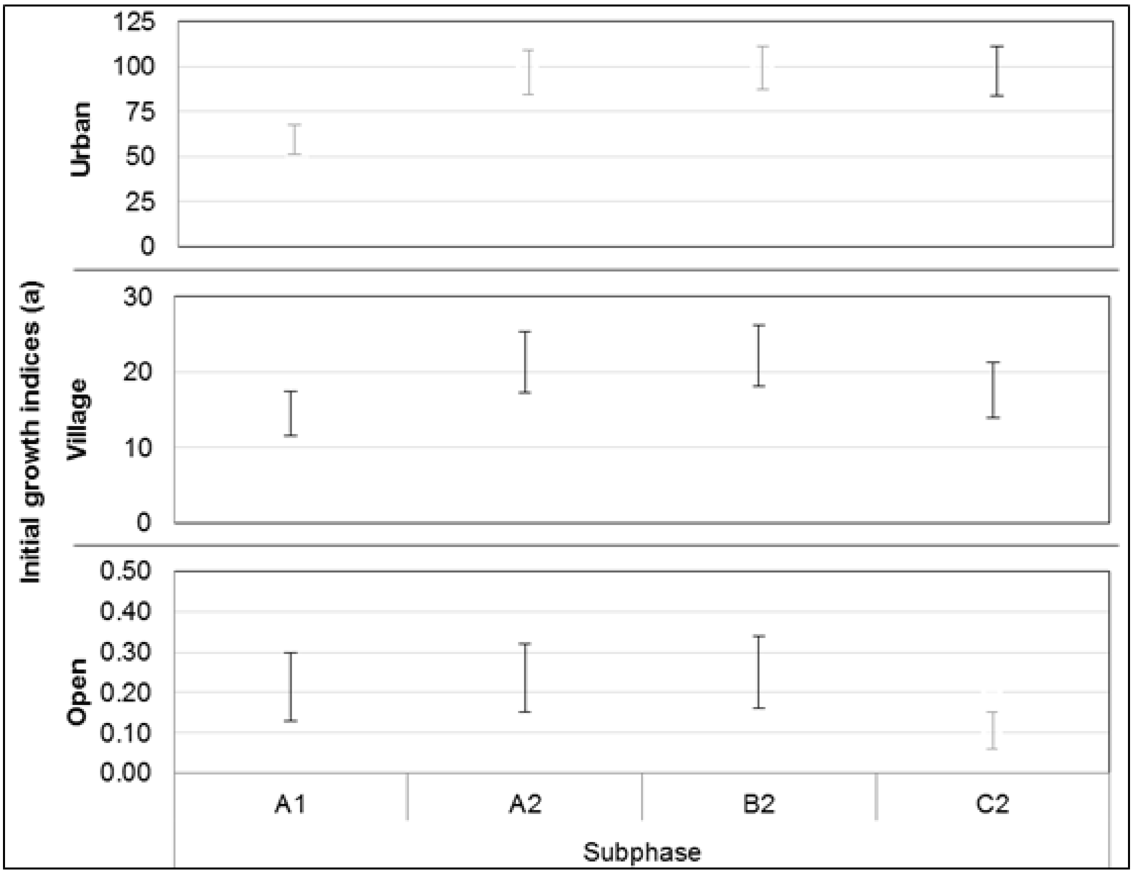


Figure 6.24. Wiessner's (1974) AGF2 open, village and urban initial growth indices for Beidha Subphases A1 to C2. Results in lighter grey indicate where the subphase does not conform to that particular settlement type.

6.6.5 Settlement population density coefficient method (SPDC)

SPDC methods were applied to (1) assess the suitability of commonly utilised SPDCs (90, 150 and 294 people/ha) for estimating the population of PPN Beidha and (2) to reconstruct SPDCs from population estimates based on other methods.

The first method applies the commonly utilised SPDCs to total site extent. There appears to be several issues with this method. Firstly, the same population estimates were produced for subphases with the same estimated site extent (i.e. Subphases A2 and B2: 0.2 ha) (Table 6.43; Figure 6.25). In addition, the large range in the commonly utilised SPDCs (90 to 294 people/ha) causes increasingly broader population estimate ranges as site extent increases.

When adjusted to reflect population and dwelling occupant numbers in the assessable area only, it is apparent that commonly utilised SPDCs may underestimate population. Even when dwelling numbers were reduced to reflect potential structural contemporaneity (all subphases c. 70-78%), the minimum SPDC (90 people/ha) resulted in average dwelling unit sizes of less than one person in all subphases, whilst the average SPDC (150 people/ha) produced average estimates of less than one person in Subphases A1, A2 and B2 and just over one person in Subphase C2. Application of the maximum SPDC (294 people/ha) produced average dwelling unit sizes of one person for Subphases A1, A2 and B2, and around 2.5 people in Subphase C2. If dwellings were indeed occupied by nuclear families, as Byrd (2005a) suggests, this could reflect two adults and a child. However, it is highly improbable that these highly compartmentalised, two-storey dwellings with considerable ground floor storage space and large upper storey residential areas were occupied by such small units.

Given that dwellings at Beidha are considered to have been predominantly occupied by nuclear families of around five to six people (Byrd 2005a), it is apparent that the commonly utilised values for population density and dwelling unit size are not compatible. There could not have been a population density of 294 people per hectare or fewer on the one hand and a dwelling occupant size of five to six people on the other. The results do not correlate. Either the population density was higher or the dwelling unit size was smaller. It appears that these commonly utilised values and the theory that PPN dwellings were occupied by nuclear families of five to six people need to be reconsidered.

As part of this re-evaluation, SPDCs were calculated from HUM, RADC and SPF population estimates and converted to population and average dwelling unit size in the assessable area. Re-calculated SPDCs ranged from around 280 people per hectare (Subphase B2: based on the RADC population estimate) to 1,730 people per hectare (Subphase A1: based on the HUM population estimate). All SPDCs, except the lowest mentioned above, were higher than the maximum commonly utilised SPDC (294 people/ha). The revised SPDCs all produce more realistic estimates of population and dwelling unit size in the assessable area (Table 6.43).

The SPDC method is a simple tool for rapidly estimating population for comparative analysis. However, the reliability of the method for producing absolute estimates depends on the suitability of the density coefficients employed. For the PPN settlement at Beidha, it appears that the commonly utilised SPDCs (90-294 people/ha) are too low to accurately estimate population.

Table 6.43. SPDC method results for Beidha Subphases A1 to C2.

		Subphase			
		A1	*A2*	*B2*	*C2*
Method 1: Population estimates based on commonly utilised SPDCs					
	SPDC (people per hectare)				
Total population estimate	90	9	18	18	27
	150	15	30	30	45
	294	29.4	58.8	58.8	88.2
Population in the assessable area	90	1.2	2.6	5.4	8.6
	150	2.0	4.4	9.0	14.4
	294	3.9	8.6	17.6	28.2
	Based on proportion of site assessable (%)	*13.22*	*14.68*	*30.00*	*31.92*
People per dwelling in the assessable area	90	0.4	0.4	0.4	0.7
	150	0.7	0.7	0.6	1.2
	294	1.4	1.3	1.2	2.4
	Based on estimated contemporaneous dwellings in the assessable area	*2.86*	*6.75*	*15.02*	*11.67*
Method 2: SPDC estimates based on HUM, RADC and SPF population estimates					
SPDC (people per hectare)	HUM	648.53-1729.41	689.9	751.1	365.49-974.65
	RADC	419.84-1185.99	297.07-839.18	282.91-799.17	335.36-947.34
	SPF	573.32-864.36	394.71-578.08	381.69-552.97	468.56-719.23
Based on population estimate	*HUM*	*64.85-172.94*	*137.98*	*150.22*	*109.65-292.39*
	RADC	*41.98-118.6*	*59.41-167.84*	*56.58-159.83*	*100.61-284.2*
	SPF	*57.33-86.44*	*78.94-115.62*	*76.34-110.59*	*140.57-215.77*
Population in the assessable area	HUM	8.6-22.9	20.30	45.10	35-93.3
	RADC	5.5-15.7	8.7-24.6	17-47.9	32.1-90.7
	SPF	7.6-11.4	11.6-17	22.9-33.2	44.9-68.9
	Based on proportion of site assessable (%)	*13.22*	*14.68*	*30.00*	*31.92*
People per dwelling in the assessable area	HUM	3-8	3	3	3-8
	RADC	1.9-5.5	1.3-3.7	1.1-3.2	2.8-7.8
	SPF	2.7-4	1.7-2.5	1.5-2.2	3.8-5.9
	Based on estimated contemporaneous dwellings in the assessable area	*2.86*	*6.75*	*15.02*	*11.67*

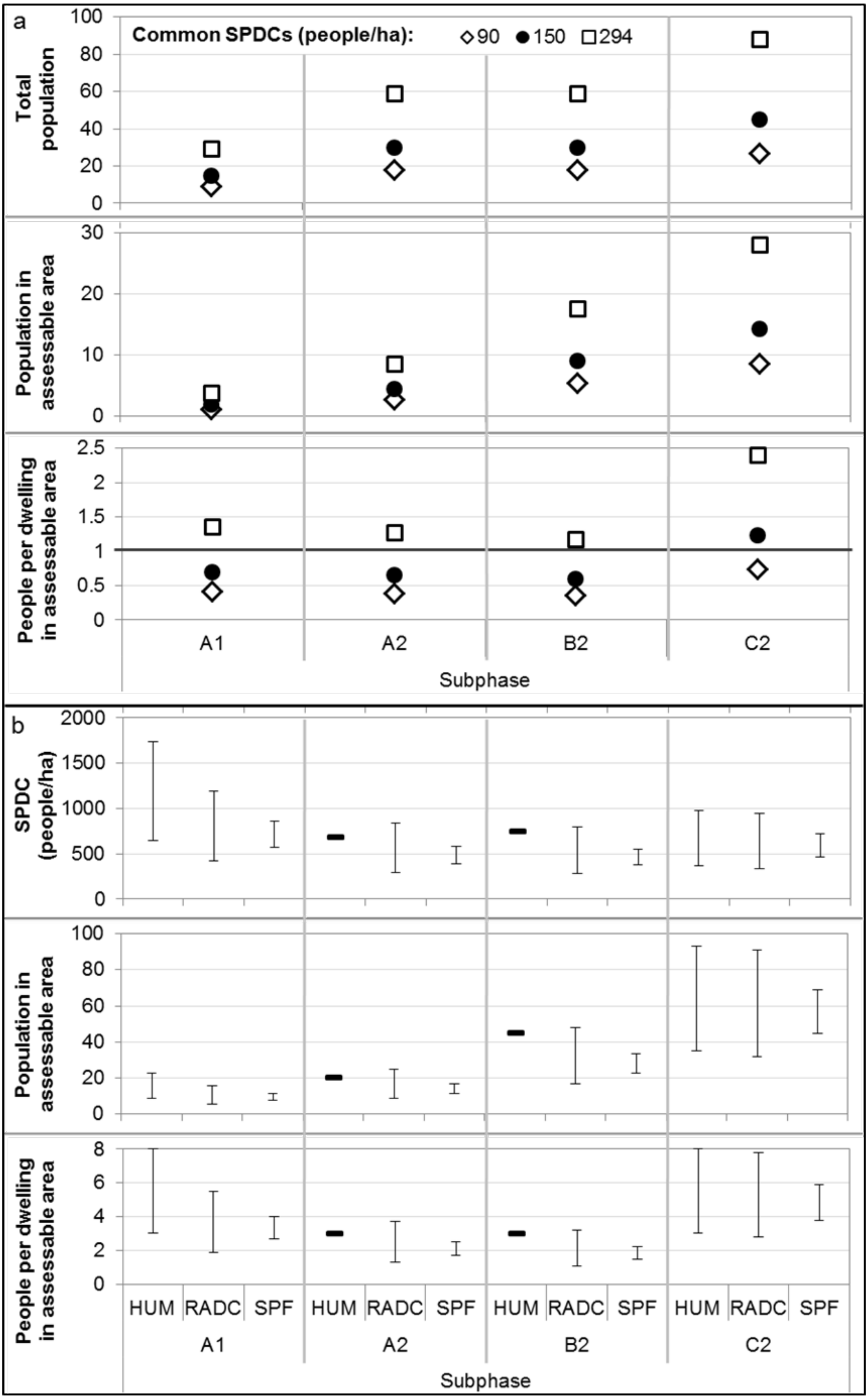


Figure 6.25. Data derived from SPDC methods for Beidha Subphases A1 to C2: (a) data derived from commonly utilised SPDCs; (b) data derived from HUM, RADC and SPF population estimates.

6.7 Summary of estimates

This section provides a summary of estimates of total population, population growth, the number of people per dwelling, residential floor area per person (RADC), the number of people per hectare (SPDC), initial growth indices (AGF1 and 2) and area proportions (Table 6.44; Figure 6.26). As the SPF is considered the most empirically robust and valid method (see Section 10.2.1), SPF estimates are presented as the final estimates for further analysis.

6.7.1 Total population

The SPF indicated a total (adult) population of around 55 to 85 people in Subphase A1; 80 to 115 people in Subphase A2; 75 to 110 people in Subphase B2; and 140 to 215 people in Subphase C2. Kuijt's (2008, p.294) estimate for the final phase (P = 225) compares well with the higher estimate derived in this investigation, although his calculations were based on a density coefficient of 90 people per hectare (including children) and an average period-based site extent of 2.5 hectares (for the MPPNB), which is far in excess of the estimated extent for this subphase (0.3 ha).

Estimates for Subphases A2 and B2 were almost equivalent on account of several factors, including equivalent site extent (0.2 ha); comparable mean residential floor area per dwelling (c. 7 m^2); and the use of Subphase A2 area proportions for Subphase B2 calculations due to the destruction of much of the Subphase B2 occupation by later construction. For this latter reason also, it is probable that Subphase B2 population size has been underestimated. Given the agricultural and architectural developments occurring at Beidha between Subphases A2 and B2, it is highly probable that the population exceeded that of Subphase A2.

The estimates achieved for Beidha coincide with a range of hypothesised group size thresholds relevant to settlements undergoing the NDT. Firstly, it is hypothesised that a group size of at least 25 people is required for the initial transition to sedentism (Fletcher 1981; Binford 2001; Kuijt and Goring-Morris 2002; Bandy 2010). Subphase A1 (50-90 people) provides the first evidence for a permanently settled community on this site (Byrd 2005a).

Secondly, a group size of at least 50 people is considered necessary for the transition to farming practices (Drennan and Peterson 2008), with at least 100 people required for adoption of a fully sedentary agro-pastoralist subsistence strategy (Fletcher 1981; Kuijt and Goring-Morris 2002). Archaeological evidence indicates agricultural practices relating to domesticated plant forms from Subphase B2 (75-110 people) and transition to agro-pastoralist practices by Subphase C2 (140-215 people) (Byrd 2005a).

Finally, it is theorised that groups of around 150 people either undergo fissioning processes, including the establishment of smaller 'daughter villages' (Bandy 2004; 2006), or introduce mechanisms for social cohesion (Fletcher 1981; Dunbar 2003). Cohesive elements are evident in the emergence of large, centrally-located, non-domestic structures from Subphase A2 (80-115 people) and, particularly, in Subphases B2 and C2, where several non-residential structures appear to be in simultaneous use. In the final subphase, evidence suggests some form of central or corporate management (Byrd 2005a). Elements of intra-community fissioning or sectoring are evident in the increasing household control of resources and production from Subphase A2 and is again particularly evident in Subphase C2, where individual dwellings contain considerable space for household controlled storage, and evidence for household-based production and possibly inherited specialist knowledge (Fletcher 1981; Dunbar 2003; Byrd 2005a).

6.7.2 Population growth

The consecutive phases at Beidha present a rare opportunity to directly calculate population growth. The SPF population estimates and estimated subphase lengths produced annual population growth rates of around 0.2% to 0.3% between Subphases A1 and A2; -0.1% to Subphase B2; and 1.2% to 1.4% to Subphase C2. These rates fall within the range calculated for the MPPNB (-1.3%-1%) and LPPNB (-0.75%-2.1%) by Goodale (2009, p.160). The mean annual population growth rate throughout all phases is around 0.5%. This compares well with Eshed *et al.*'s (2004) estimate of 0.5% to 1% for southern Levantine communities at the advent of agriculture.

The comparatively high growth rate between Subphases A1 and A2 probably reflects the initial and increasing transition to a fully sedentary existence and may indeed have been the cause of this transition. The reduced (and perhaps negative) growth rate to Subphase B2 is probably due to an underestimation of population as a result of depleted occupational evidence. If such low growth did actually occur during this stage, it may suggest that the population had reached carrying capacity, which could explain the emergence of agricultural practices during Phase B. The high growth rate to Subphase C2 probably reflects a "boom" period following the transition to agro-pastoralist subsistence practices. This growth pattern is well documented in early

Neolithic settlements (Whitehouse *et al.* 2014). This high growth also probably reflects the architectural revolution from curvilinear to multi-storey, rectilinear structures, which enabled higher density housing.

6.7.3 <u>People per dwelling</u>

The SPF produced average (adult) dwelling unit size estimates of around 2.7 to 4.2 people in Subphase A1; 1.7 to 2.5 people in Subphase A2; 1.5 to 2.2 people in Subphase B2; and 3.9 to 6.4 people in Subphase C2. These estimates correspond to variations in the mean residential floor area, with larger areas occurring in Subphases A1 (11.56 m^2) and C2 (17.15 m^2), and smaller areas in Subphases A2 (7.26 m^2) and B2 (6.52 m^2).

The lower dwelling occupant numbers produced in Subphases A2 and B2 could reflect erroneous interpretation of smaller structures as representing residential space and larger structures as representing non-residential space. It is also probable that later construction destroyed more substantial Subphase B2 residential structures.

The results indicate that nuclear families could have formed the main dwelling unit in Subphases A1 and C2. However, estimates suggest paired occupancy on average in Subphases A2 and B2. These results challenge the current theory that nuclear families formed the main dwelling unit throughout the PPN sequence at Beidha (Byrd 2005a) and could support the theory that individual structures within circular hut compounds were occupied by individuals or smaller units as part of a larger family group (Flannery 1972). However, it must be emphasised that SPF estimates are based on adult human heights and, thus, that the estimated dwelling unit sizes would be higher if the formulae were amended to consider children.

Subphase C2 dwelling unit size estimates are considerably higher than those derived for the previous phases. This potentially reflects the changing structure of the residential unit in terms of increasing household institutionalisation (Byrd 2005a; Baird *et al.* 2016). In addition, architectural developments, including substantial upper storey residential area, greater compartmentalisation and more restricted access routes, enabled increased residential density whilst satisfying needs of privacy and personal space.

A comparison of population estimates derived from the HUM and SPF methods revealed potential correlations between dwelling unit size and residential architectural forms. During Subphases A1, A2 and B2, residential architecture predominantly comprised curvilinear dwellings with undifferentiated residential floor space; whilst in Subphase C2, residential architecture comprised two-storey, highly compartmentalised dwellings, with large upper storey residential areas and substantial ground floor area for storage and additional activities (Byrd 2005a). For the subphases with curvilinear architecture, estimates derived from the HUM were considerably higher than those of other methods. This occurred even when employing the minimum nuclear family size only, as was the case for Subphases A2 and B2, where the available mean residential floor area (c. 7 m^2) afforded on average paired dwelling occupancy. This could indicate that nuclear families did not form the main dwelling unit in these subphases. Conversely, the HUM estimate for Subphase C2, which employed all nuclear family sizes, was more comparable to the SPF estimate. This highlights the potential for nuclear family dwelling units in the latest phase.

6.7.4 Residential floor area per person

The SPF method produced estimates of 2.3 m^2 to 3.8 m^2 residential floor area per person across all phases, with marginally higher minimum personal space allocation for Subphases A2 and B2 (c. 2.6 m^2). The RADCs fall within the range derived from ethnographic studies of comparable villages and the range utilised in RADC population estimates in this investigation (1.77-5 m^2). Interestingly, despite the larger available residential floor area in Subphases A1 and C2, the results do not suggest an increase in personal space allocation. The comparability in RADCs across all phases is probably partly due to the SPF method. For each subphase, estimates were based on the SPF for limited storage (none to moderate). This produced similar correlations between the number of occupants and available space.

An assessment of RADCs produced via other methods highlights some interesting information. Firstly, RADCs based on the HUM for Subphases A2 and B2, which employed the minimum nuclear family size (3 people) only, suggest that these dwellings may not have accommodated nuclear families. Population estimates based on the average and maximum nuclear family sizes (5.5 and 8 people) would have produced RADCs considerably lower than the minimum RADC employed in this investigation (1.77 m^2).

Secondly, the comparability between the Subphase C2 RADCs derived from the AGF1 (4-4.3 m^2) and the SPF (2.3-3.6 m^2) compared to other subphases potentially supports the suitability of Naroll's (1962) formula for settlements with agglomerated, rectilinear architecture.

Thirdly, the SPDC method produced excessive RADC ranges. The maximum RADCs derived from the SPDC method (based on 90 people/ha) exceeded the mean residential floor area of complete dwellings in all subphases. This provides further support for the re-evaluation of SPDCs commonly utilised for estimating PPN village population.

6.7.5 People per hectare

The SPF method produced population density coefficients (SPDCs) of around 575 to 865 people per hectare for Subphase A1; 395 to 580 people per hectare for Subphase A2; 380 to 555 people per hectare for Subphase B2; and 470 to 720 people per hectare for Subphase C2. Despite being based on adult population only, these SPDCs far exceed the range commonly used for estimating PPN central and southern Levantine populations (90-294 people/ha). The SPDCs produced in this analysis are more comparable to those derived for enclosed Bronze Age settlements (Ugarit, Syria: 550 people/ha; Mesopotamia: 380-750 people/ha) (Wossinik 2009; Kennedy 2013) and Iron Age settlements (Palestine: 400-500 people/ha; Jerusalem: 395 people/ha) (Jeremias 1969; Shiloh 1980; Zorn 1994). These estimates also compare well with SPDCs derived for several hunter-gatherer camps, including coastal Tlingit fishing and hunting communities (327 people/ha), Mbuti tropical forest hunters (820 people/ha) and the desert savannah !Kung (804 people/ha) (Whitelaw 1983, p.60).

The high SPDCs may reflect the spatial restrictions on the settlement at Beidha due to the topographical context and the placement of a village wall bounding the settlement to the south. However, it is improbable that settlement sprawl was restricted in any significant way given the low estimated population sizes for all phases and the open spatial distribution of structures particularly in Phases A and B. This is further supported by the combination of population increase with declining density from Subphases A1 to A2. It is more probable that the high SPDCs are probably due to the nature of the architectural construction, which included clustered and interconnected, curvilinear dwellings in Phases A and B, and high density, interconnected, two-storey, rectilinear housing in Phase C. Further analysis will reveal whether high SPDCs were a characteristic of PPN villages in the central and southern Levant.

Table 6.44. Estimates for Beidha Subphases A1 to C2. SPF estimates considered most reliable and highlighted in grey for comparative analysis.

	Subphase			
	A1	*A2*	*B2*	*C2*
Total population				
HUM	65-175	140	150	110-290
RADC	40-120	60-170	55-160	100-285
SPF	55-85	80-115	75-110	140-215
SPDC	10-30	20-60	20-60	25-90
Annual population growth rate (%)				
Estimated subphase length	*140*	*80*	*70*	*90*
HUM		-0.14-0.81	0.11	-0.39-1.35
RADC		0.3	-0.06	1.11
SPF		0.24-0.27	-0.04- -0.05	1.2-1.36
SPDC		0.71	0	0.71
People per dwelling				
Total number of contemporaneous dwellings	*21.62*	*45.99*	*50.07*	*36.55*
Mean residential floor area of complete dwellings (m^2)	*11.56*	*7.26*	*6.52*	*17.15*
HUM	3-8	3	3	3-8
RADC	1.9-5.5	1.3-3.7	1.1-3.2	2.8-7.8
SPF1	2.7-4	1.7-2.5	1.5-2.2	3.9-5.9
SPF2	2.9-4.2	1.8-2.5	1.7-2.2	4.3-6.4
SPDC	0.4-1.4	0.4-1.3	0.4-1.2	0.7-2.4
RADC (m^2 per person)				
Total contemporaneous residential floor area (m^2)	209.92	297.07	282.91	503.04
HUM	1.2-3.2	2.2	2.2	1.7-4.6
RADC	1.77-5			
SPF	2.4-3.7	2.6-3.8	2.6-3.7	2.3-3.6
AGF1	9.2-9.8	6.8-7.2	6.9-7.3	4-4.3
SPDC	7.1-23.3	5.1-16.5	4.8-15.7	5.7-18.6
SPDC (people per hectare)				
Total site extent (hectares)	0.1	0.2	0.2	0.3
HUM	650-1730	690	750	365-975
RADC	420-1185	295-840	285-800	335-945
SPF	575-865	395-580	380-555	470-720
SPDC	90-294			

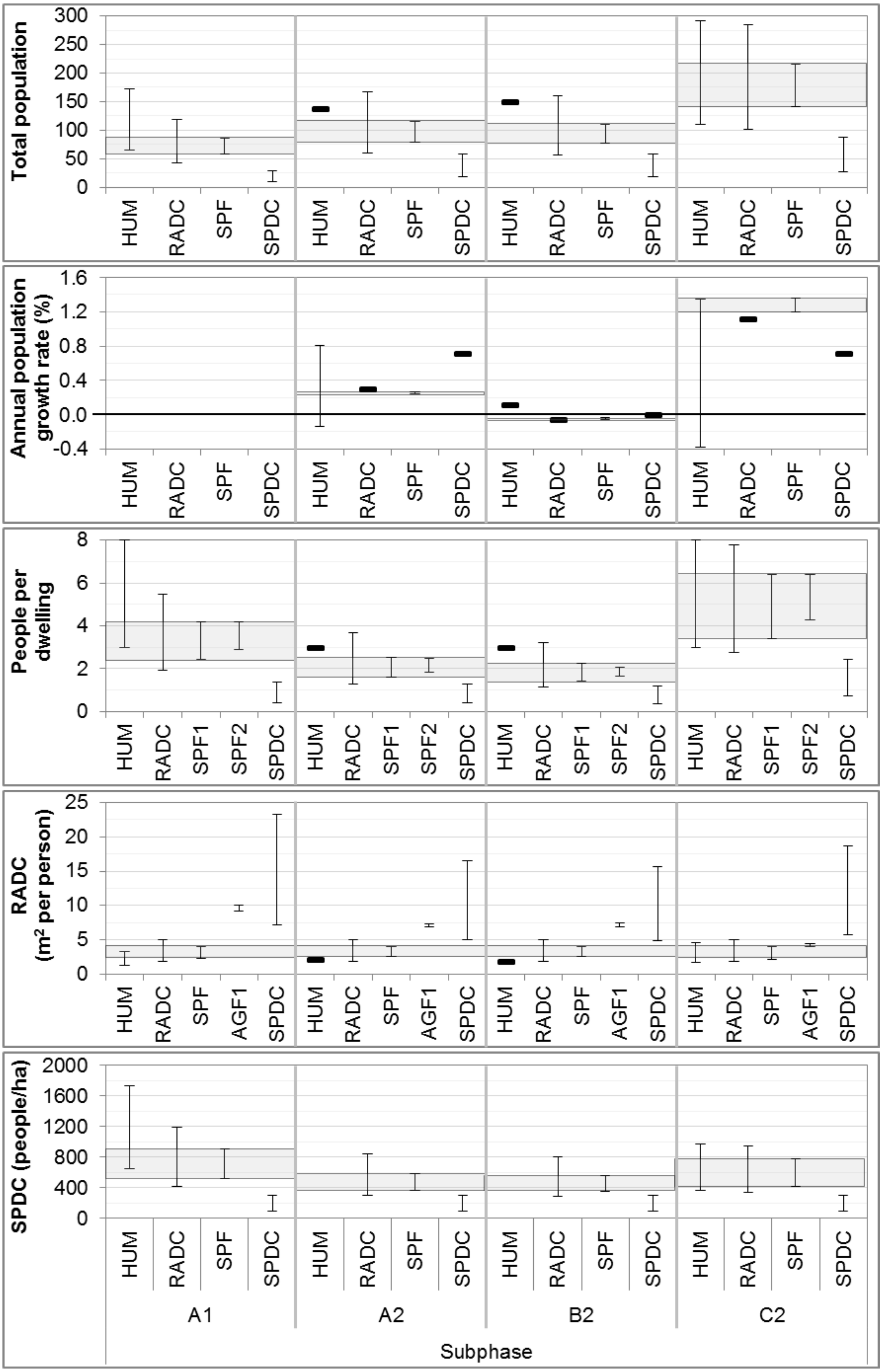


Figure 6.26. Estimates for Beidha Subphases A1 to C2. SPF estimates considered most reliable and highlighted in grey for comparative analysis.

6.7.6 Initial growth indices for the allometric growth formulae

Naroll's (1962) AGF1

Re-calculation of the initial growth index utilised in Naroll's (1962) AGF1 (*a* = 21.7) produced relatively consistent values for Subphases A1, A2 and B2 (min: c. 8-11; max: c. 11-15), and a range comparable with the original index for Subphase C2 (c. 16-23) (see Table 6.4.1). The comparability between constants derived for sites exhibiting predominantly curvilinear architecture (Subphases A1, A2 and B2) and predominantly rectilinear architecture (Subphase C2 and Naroll's (1962) original dataset) indicate the potential for Naroll's (1962) formula to be refined for different settlement types.

Wiessner's (1974) AGF2

The initial growth index calculated for Wiessner's (1974) AGF2 for village settlements was relatively consistent across all phases (min: c. 12-18; max: c. 17-26), suggesting that an average index range of around 15 to 23 may be suitable for estimating the population of all PPN central and southern Levantine villages when applying this formula (see Table 6.4.2). Similarly, the comparability between indices derived for open settlement types (Subphases A1, A2 and B2) (min: 0.13-0.16; max: 0.3-0.34) indicates that an average index range of around 0.15 to 0.32 may be suitable for application of the open AGF2 to PPN villages with curvilinear architecture. In this preliminary analysis, only one phase demonstrated characteristics of an urban settlement (Subphase C2). Thus, further analysis is required prior to the assessment of indices for this settlement type.

6.7.7 Area proportions

The methods explored in this investigation have provided a range of area proportions for further analysis and for the creation of formulae and constants for large-scale application (Table 6.45). All have been discussed in detail in Section 6.6, except for the proportion of built floor area comprising residential floor area. Proportions decline from around 85% in Subphase A1 to around 45% in Subphase C2. This reflects the increasing differentiation between residential and non-residential space and the increasing allocation of interior dwelling area to non-domestic activities by Subphase C2 (Kirkbride 1966, p.25; Byrd 2005a).

Table 6.45. Additional demographic data derived for Beidha Subphases A1 to C2. Estimates adjusted for contemporaneity highlighted in grey.

	Subphase							
	A1		*A2*		*B2*		*C2*	
	Structural contemporaneity (%)							
		71.43		*75*		*71.43*		*77.78*
Proportion (%) of assessable area comprising:								
Built area	65.65	46.89	57.21	42.91	28.5*	40.87	59.35	46.16
Residential built area	56.63	40.45	39.79	29.85	15.14*	28.42	35.78	27.83
Built floor area	34.22	24.44	27.77	22.32	17.05*	21.26	49.67	38.63
Residential floor area	29.39	20.99	19.8	14.85	8.3*	14.14	21.56	16.77
Proportion (%) of assessable built area comprising:								
Residential built area		86.26		69.55		53.12*		60.29
Built floor area		52.13		52.02		59.83		83.69
Residential floor area		44.76		34.61		29.14		36.32
Proportion (%) of residential floor area in built floor area		85.88		66.55		66.52		43.4

* Distorted by later construction; Subphase A2 proportions used in calculations.

6.8 Summary

The PPN village at Beidha is an excellent case study for preliminary methodological analysis as it demonstrates a transition from the earliest stages of a PPN village characterised by curvilinear architecture and the maintenance of hunter-gatherer practices, to the latest stages characterised by rectilinear architecture, agro-pastoralist subsistence practices and increasing social and economic differentiation.

Application of a range of methodologies for estimating population parameters of PPN villages has revealed that the storage provisions formula (SPF) is the most empirically robust and valid method for producing absolute estimates for comparative analysis. This method relies on less ethnographic analogy and incorporates fewer assumptions than other methods explored in this investigation. It has the advantage of producing direct estimates of dwelling unit size in addition to total population size, and can highlight the potential amount of storage within the residential floor area.

The SPF method indicates that the (adult) population of Beidha increased from around 55 to 85 people in Subphase A1 to around 140 to 215 people in Subphase C2, with a mean annual population growth rate of around 0.5%. These estimates correspond well with current group size threshold theory relating to the initial transition to sedentism ($P \geq 25$); the adoption of farming practices ($P \geq 50$) and agro-pastoralist practices ($P \geq 100$); and the introduction of mechanisms for social cohesion within larger groups ($P \geq 150$) (Fletcher 1981; Binford 2001; Kuijt and Goring-Morris 2002; Dunbar 2003; Drennan and Peterson 2008; Bandy 2010). The population growth rate also compares well with those derived for early agricultural and formative villages throughout the world

(0.08-1%) (Carneiro and Hilse 1966; Hassan 1981; Bandy 2001; Eshed *et al.* 2004; Drennan and Peterson 2008).

Preliminary analysis indicates that current theory relating to population density and the composition of the dwelling unit, as well as methodological practices relating to commonly utilised values for the number of people per dwelling, residential floor area per person (RADC) and the number of people per hectare (SPDC) require re-evaluation. For decades, nuclear families have been considered to represent the main dwelling unit in Neolithic societies (Sweet 1960; Haviland 1972; Kramer 1982; Düring 2001; Byrd 2002; 2005a). However, this analysis indicates that nuclear family dwelling units may not have occurred within some PPN settlements, especially those with predominantly curvilinear dwellings.

Ethnographically derived RADCs are often not employed in population estimates due to the inconsistency in the measurements utilised to calculate RADC and the vast estimate ranges. However, this assessment has produced a relatively limited RADC range of 2.3 m^2 to 3.8 m^2 across all phases. It appears that changes in architecture, including increases in available residential floor area, may not have significantly altered the amount of personal residential floor area. These RADCs correspond well with archaeological and ethnographic estimates of RADC in comparable villages in Southwest Asia, Southwest America and the Arctic Circle (1.77-5 m^2 per person) (Cook and Heizer 1968; Hill 1970; Clarke 1974; Kramer 1979; Hayden *et al.* 1996; Hemsley 2008). The consistency of results indicates that this RADC range could be utilised to estimate the population of PPN central and southern Levantine villages.

Almost all PPN village population estimates to date have utilised the same simple methodology for rapidly estimating populations based on site extent and an ethnographically derived population density range of 90 to 294 people per hectare. However, this analysis indicates that this range is too low to accurately estimate the population of PPN Beidha. This investigation produced SPDCs ranging from around 380 to 870 people per hectare.

Another method for rapidly estimating population is the allometric growth formula (AGF). This method has been largely abandoned in archaeology given the variable relationship between human population size, population density and settlement size. However, re-calculation of initial growth indices utilised in these formulae has revealed that AGF may be suitable for estimating PPN central and southern Levantine villages. This analysis has revealed that Naroll's (1962) original index of 21.7, or a range from around 16 to 23 (derived from Subphase C2) may be suitable for estimating the population of PPN villages with predominantly rectilinear architecture; and that a reduced index range of around 10 to 14 (derived from Subphases A1, A2 and B2) may be suitable for application to PPN villages with predominantly curvilinear architecture.

For Wiessner's (1974) AGF2, this assessment indicates that an initial growth index range of around 15 to 23 (derived from all subphases) may be suitable when applying the AGF2 for village settlements; and an index range of around 0.15 to 0.32 (derived from Subphases A1, A2 and B2) may be suitable when applying the formula for open settlements. Further analysis is required prior to development of a suitable index range for urban settlements.

This preliminary analysis of Beidha has challenged current theory relating to the use of space within PPN central and southern Levantine villages and the application of commonly accepted constants for estimating population size. The following chapter presents the results of application of these methodologies to a further 10 sites across 11 phases to derive more precise constants for estimating PPN central and southern Levantine populations.

7 Micro-Level Estimates – Part II

This chapter presents the application of micro-level methodologies to a further 11 PPN central and southern Levantine villages/village phases ordered in ascending chronological order. For each village, a description of archaeological features and a site plan are provided, in addition to the structural contemporaneity assessment and previous population estimates. SPF population estimates are assessed in relation to previously hypothesised group size thresholds for each village (see Table 4.8 for references for each hypothesised threshold). All other population parameters are assessed in the summary of estimates. Additional results are provided in Appendices C.1 to C.2.

7.1 Micro-level analyses

7.1.1 Nahal Oren

Site description

Nahal Oren is a very small (0.05 ha) Late Epipalaeolithic (LEPI) to PPNB cave and terrace site in Mount Carmel, Israel (Stekelis and Yizraely 1963; Noy *et al.* 1973; Banning 1998, p.195; Twiss 2001; Nadel *et al.* 2012). The limited occupation evidence and restricted agricultural potential of the site suggests short-term sporadic rather than long-term continuous occupation. The most substantial occupation evidence dates to the PPNA (Stratum II). This stratum is interpreted as a village based on the presence of several durable structures that appear to have been utilised for a mixture of residential and non-residential purposes. Micro-level analysis is conducted on the Stratum II occupation only (Table 7.1; Figure 7.1).

Excavation exposed at least 13 curvilinear structures set on four terraces cut into the natural slope. Structures were predominantly semi-subterranean with thick walls (up to 80 cm wide). At least 10 structures have been interpreted as dwellings (Buildings 5, 8-9, 11-12, 14, 16, and 18-20). These structures contained stone-lined hearths, stone slabs and cup-marked stones set into packed earth and pebble flooring (Nadel *et al.* 2012). The presence of limestone bowls and platters within dwellings indicates dwelling-based food-related activities and may reflect habitation of dwellings by household economic units (Noy *et al.* 1973, p.86; Rosenberg 2008). However, Bar-Yosef (1998, p.170) suggested that the clustering of structures probably reflects occupation of dwellings by smaller units or individuals as part of an extended family compound. The location of smaller structures interpreted as stores or workshops (Buildings 7, 10 and 13) between dwellings may indicate a predominantly communal economic strategy characteristic of such compounds (Stekelis and Yizraely 1963, p.4; Finlayson *et al.* 2012).

Table 7.1. Description of Nahal Oren Stratum II* and refined variables.

Estimated site extent		500 m^2
Assessable area		326.36 m^2
Potential dwellings		10
Environment		On steep slope above Wadi Fallah; perennial watercourses; many caves
Subsistence		Hunting, gathering, cultivation (pre-domesticated cereals and grains; sickle blades); separate permanent storage and workshop structures; potential on floor storage in residential floor area
Architecture		Curvilinear; organised in clusters; semi-subterranean; thick stone walls; organic roofing; artificial terraces; no/very few subdivisions or compartmentalisation; some remodelling
Economy		Dwelling-based processing and consumption (vessels and grinding implements in dwellings); communal processing and cooking (stores and workshops in communal area); incipient craft specialisation (workshops; food vessels; one figurine); possible broader network with several Mount Carmel cave sites
Ritual/community organisation		Incipient ritual activity: one figurine
Structural contemporaneity		80%
Refined variables:	HUM	Minimum-average (maximum nuclear family size excluded based on insufficient mean residential floor area (9.6 m^2))
	AGF2	Open and village

* Stekelis and Yizraely 1963, Noy *et al.* 1973, Twiss 2001, Nadel *et al.* 2012.

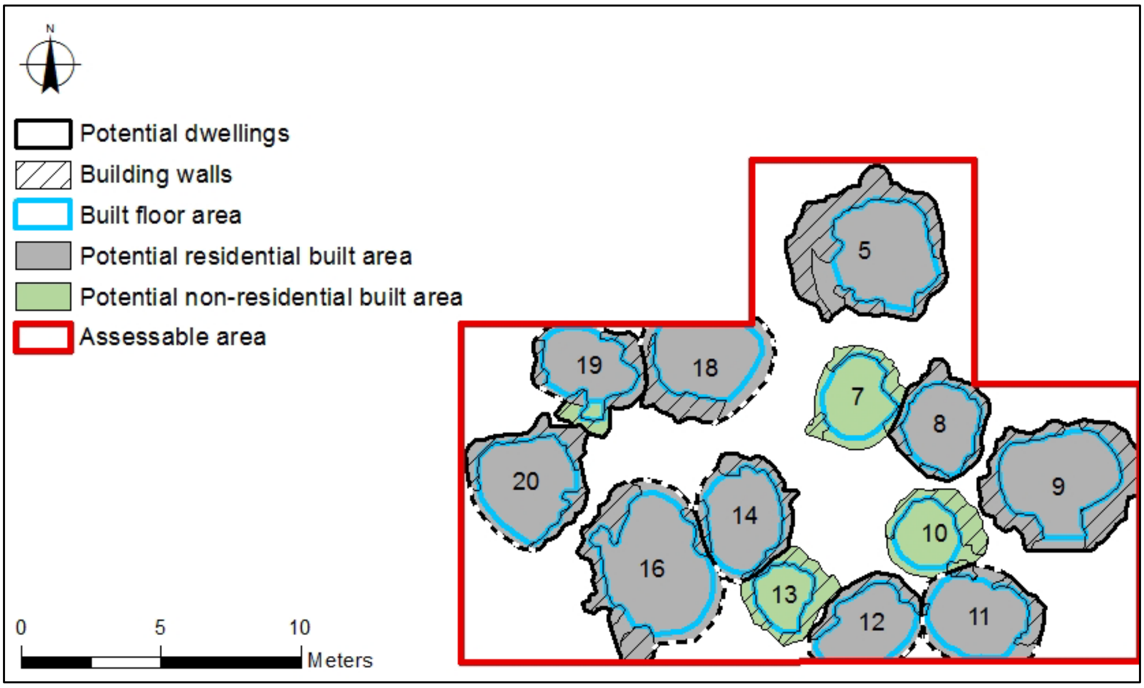


Figure 7.1. Site plan of Nahal Oren Stratum II (transcribed from Goring-Morris and Belfer-Cohen 2008, p.259).

Contemporaneity assessment

The considerable effort required for excavating terraces from the natural hillside and evidence for floor renewal and wall remodelling indicates that structures were utilised for an extended period. Analysis of comparable structures (earthen/masonry with moderate-considerable maintenance) has produced use-life estimates of around 35 to 75 years (see Table 5.7). Only one radiocarbon date is available for the PPNA occupation at Nahal Oren (9,194 to 8,558 cal BC; OxA 5010: 9480 ± 100 BP). As such, building use-life and phase length estimates could not be derived from Bayesian chronological modelling. A suggested structural contemporaneity value is, therefore, based on those derived for the most comparable sites in this investigation (i.e. Beidha Subphases A1: 71.43% and A2: 75%; Shkārat Msaied: 80%). The lack of evidence for superpositioning or building abandonment during the Stratum II occupation at Nahal Oren suggests that most structures were utilised contemporaneously. Therefore, a contemporaneity value at the higher end of this range (80%) is utilised.

Previous population estimates

The population of PPNA Nahal Oren has previously been estimated at between 18 and 59 people based on the commonly utilised density coefficient range of 90 to 294 people per hectare and an estimated total site extent of 0.2 hectares (Kuijt 2000). An alternative estimate of 90 people was based on 90 people per hectare and a suggested average total site extent of one hectare for PPNA settlements (Kuijt 2008a). A third estimate of 332 people was based on the population estimate derived for the largest five PPNA settlements and a density of 294 people per hectare (Kuijt 2000).

Population estimates and group size thresholds

The SPF indicates a total (adult) population of around 24 to 43 people, around two to 3.5 people per dwelling, around 2.6 m^2 to 4.7 m^2 residential floor area per person and around 490 to 860 people per hectare (Table 7.2; Figure 7.2). The population estimate is at the lower end of the pre-existing estimate range (18-332 people). The estimate coincides with hypothesised group size thresholds relevant to the NDT relating to the transition from a nomadic tribal camp (P = 10-30) to a sedentary tribal hamlet or village (P ≥ 25). Archaeological evidence exists for emerging specialisation and differentiation between residential units, as indicated by variable association of dwellings with annexes and workshops, which is usually associated with higher population levels (P ≥ 150). Excavations on Mount Carmel have revealed at least five additional PPNA sites within one kilometre of Nahal Oren (Nadel *et al.* 2012). It is possible that these sites formed a broader social network, which could explain the presence of such processes at Nahal Oren despite the low estimated population size.

Table 7.2. Summary of estimates for Nahal Oren Stratum II.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		12.25	*113.30*	*0.05*
HUM	36.74-67.36	3-5.5	1.68-3.08	734.8-1347.2
RADC	22.66-64.01	1.85-5.23	1.77-5	453.19-1280.21
SPF1	24.37-43.05	1.99-3.51	2.63-4.65	487.39-860.98
SPF2[a]	-	2.19-3.41	-	-
AGF1[a]	-	-	10.35-11.3	-
SPDC	4.5-14.7	0.37-1.2	7.71-25.18	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage: None ($P = 43.05$)	Moderate ($P = 28.82$)	Minimum ($P = 24.37$)
Naroll's (1962) AGF1		6.90	9.67	11.13
Wiessner's (1974) AGF2	Open settlements	0.27	0.60	0.84
	Village settlements	11.61	17.35	20.52
	Urban settlements	40.70	53.18	59.48

Additional demographic data			*Contemporaneous (80%)*
Proportion (%) of assessable area comprising:	Built area	54.69	43.75
	Residential built area	46.19	36.95
	Built floor area [b]	32.76	26.20
	Residential floor area	28.32	22.66
Proportion (%) of assessable built area comprising:	Residential built area	84.46	
	Built floor area [c]	59.89	
	Residential floor area	51.79	
Proportion (%) of built floor area comprising residential floor area		86.47	
Mean residential floor area of complete dwellings (m^2)		9.60	

[b] Based on assessable area (326.36 m^2) and built floor area (106.9 m^2).
[c] Based on assessable built area (178.48 m^2) and built floor area (106.9 m^2).

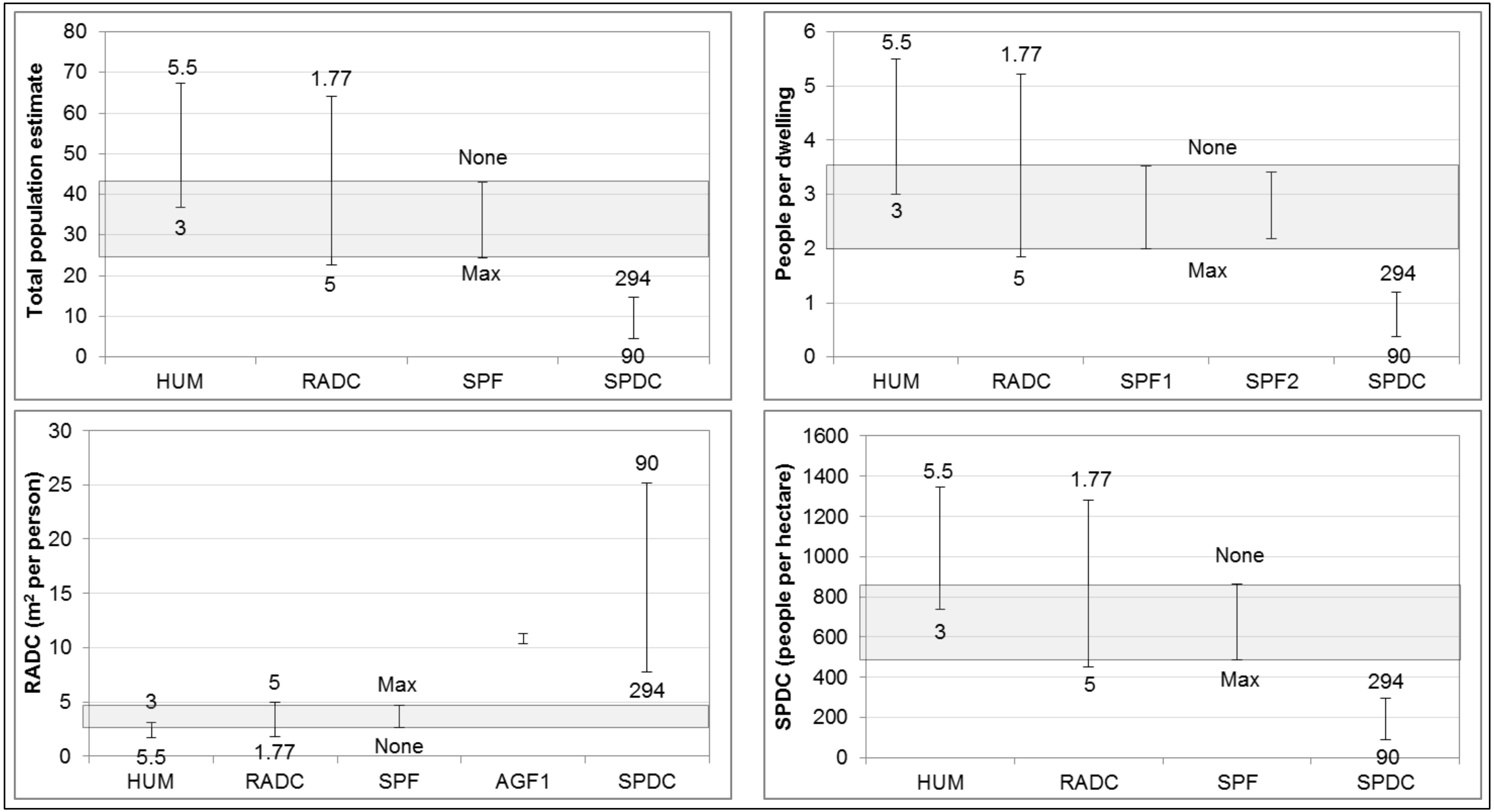


Figure 7.2. Summary of estimates for Nahal Oren Stratum II.

7.1.2 Gilgal I

Site description

Gilgal I is a PPNA village in the West Bank, Palestine (Table 7.3; Figure 7.3). It forms part of a complex of sites in the Salibiya basin with Gilgal III and IV, also assigned to the PPNA (Bar-Yosef *et al.* 2010a, p.8). Gilgal I to IV are located on ridge tops, spanning around 1.0 to 1.5 hectares (Bar-Yosef *et al.* 2010a, p.7). Based on an assessment of the relative settlement size of each of these sites, depicted by Bar-Yosef *et al.* (2010a, p.4), a site extent of 0.4 hectares is proposed for Gilgal I in this investigation. Evidence exists for more than one phase, with occupation debris at least two meters deep (Noy 1989, p.17; Bar-Yosef *et al.* 2010a, p.23).

Excavations exposed at least 14 curvilinear, stone-walled structures originally interpreted as "round houses" (Noy 1979, p.233; 1989, p.12). More detailed analysis identified five as potential dwellings (Loci 1 [not depicted in Figure 7.3], 3, 5, 10 and 12) (Bar-Yosef *et al.* 2010a, p.11). Loci 4 and 7 display sufficient comparable evidence for assessment as potential dwellings in this investigation. These contained ground stone artefacts, including mortars, pestles, querns and cup-marked slabs; occasional hearths; and similar objects outside the dwellings, which may have been associated with external household or communal activities. Locus 10 also contained a bowl, hammerstone, figurines and human remains.

Table 7.3. Description of Gilgal I* and refined variables.

Estimated site extent	4,000 m^2
Assessable area	214.66 m^2
Potential dwellings	6 (Locus 1 not included as not in site plan)
Environment	On edge of a spur on the Gilgal Ridge; above large, fertile basin
Subsistence	Hunting, gathering, cultivation (wild barley and oats; seedless figs); silo with seeds in Locus 11; separate potential permanent storage structures; possible on floor storage in residential area
Architecture	Mostly curvilinear; one rectilinear; organised in clusters; stone walls covered with mud or daub; clay floors with white surface; light organic roofing; moderate subdivisions or compartmentalisation; some superpositioning, remodelling and abandonment
Economy	Dwelling-based production, processing and consumption (vessels and grinding tools in dwellings; annexed storage/work structures); communal cooking and storage (few hearths in dwellings; pits in communal areas); incipient craft specialisation (stone vessels, tools, figurines, imported material); part of a Salibiya basin society, including Gilgal sites I to VI
Ritual/community organisation	Incipient ritual activity: one central non-domestic rectilinear building (Locus 11) with seeds, large hearth, miniature grinding tools and figurines
Structural contemporaneity	60%
Refined AGF2 variables:	Open and village

* Noy 1989; Colledge 2001; Weiss *et al.* 2006; Rosenberg 2008; Zeder 2009; Bar-Yosef *et al.* 2010a; 2010b.

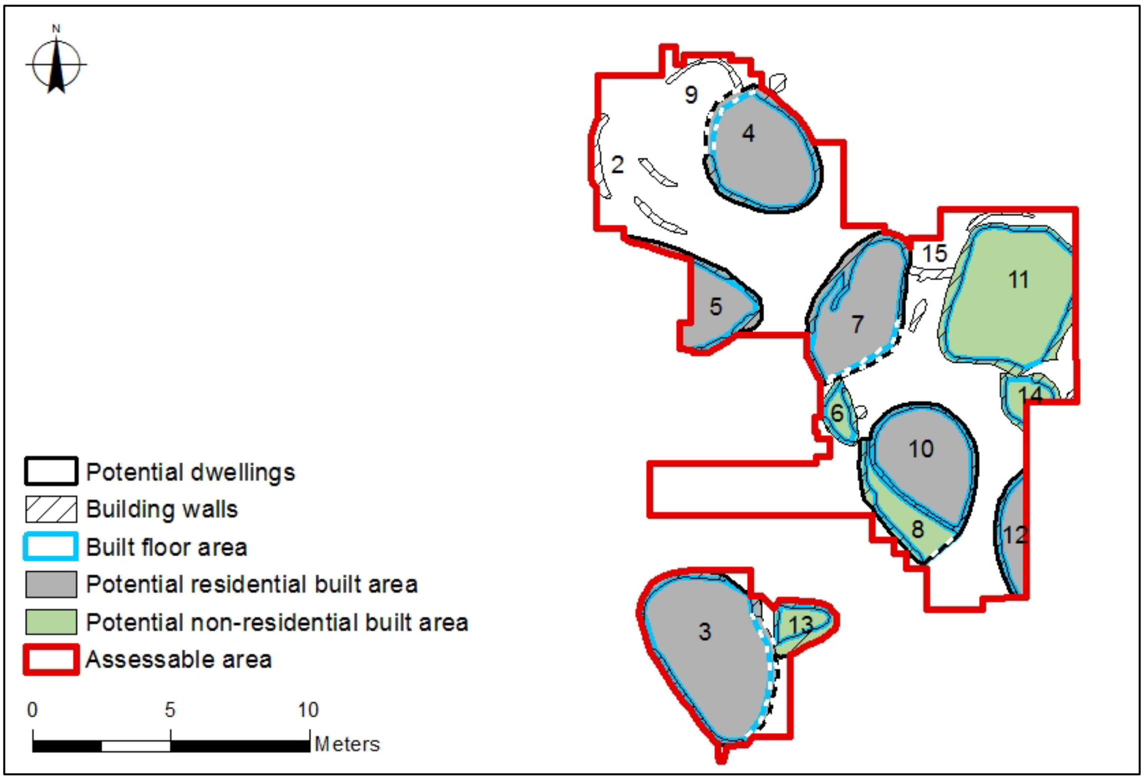


Figure 7.3. Site plan of Gilgal I (transcribed from Bar-Yosef *et al.* 2010a, p.11).

Contemporaneity assessment

Building use-life estimates derived from analysis of similar structures, including relatively thin stone walls, light organic roofing and limited evidence for remodelling, partitioning and addition of annexes (Bar-Yosef *et al.* 2010a, pp.24-25) suggest relatively short habitation of between 10 and 55 years (see Table 5.7).

Previous analysis of radiocarbon dates also indicated a relatively short period of occupation (Boaretto *et al.* 2010, p.34; Bar-Yosef *et al.* 2010b, p.300). Unfortunately, the radiocarbon determinations (n = 5) have very limited information regarding context or source material. Date RT 777-A has a large standard deviation (9,900 ± 220 BP) resulting in a broad calibrated date range (10,418-8,750 cal BC). A χ^2 test (df = 4, T = 5.3 (5% 9.5)) indicated that the dates conform to one coherent stratigraphic group, with a centre date of 9,360 to 9,250 cal BC. A single phase model highlighted no divergent dates (all agreement values A ≥ 60%). The model indicated a start date of *9,880 to 9,250 cal BC*, an end date of *9,340 to 8,830 cal BC* and a span of up to 520 years (Table 7.4; Figure 7.4).

Lack of phasing information for dates prevented estimation of phase length. Therefore, a contemporaneity value could not be directly derived for Gilgal I. Contemporaneity values derived for the village with the most comparable architecture and spatial layout in this investigation range is around 60% (Netiv Hagdud). Evidence for superpositioning and abandonment of structures at Gilgal I indicates relatively low contemporaneity. Therefore, the contemporaneity value of 60% is also considered suitable for Gilgal I.

Table 7.4. Modelled boundary dates and span estimates for Gilgal I.

Lab reference	Material	Radiocarbon date (BP)	Radiocarbon date range (cal BC) (95%)	Posterior density estimate range (cal BC) (95.4%)	Indices Amodel=146.2 Aoverall=148.2	
					A	*C*
Start Gilgal I				*9880-9250*		*95.8*
RT 777-A	CH	9900 ± 220	10420-8740	9660-9110	134.3	99.6
RT 777-B	CH	9950 ± 150	10110-9140	9630-9170	112.5	99.6
Pta 4588	CH	9920 ± 70	9750-9250	9530-9240	115.7	99.7
Pta 4583	CH	9830 ± 80	9660-9140	9450-9190	127.4	99.8
Pta-4585	CH	9710 ± 70	9300-8830	9360-9120	108.4	99.5
End Gilgal I				*9340-8830*		*97.4*
Span Gilgal I				**0-520**		**98.8**

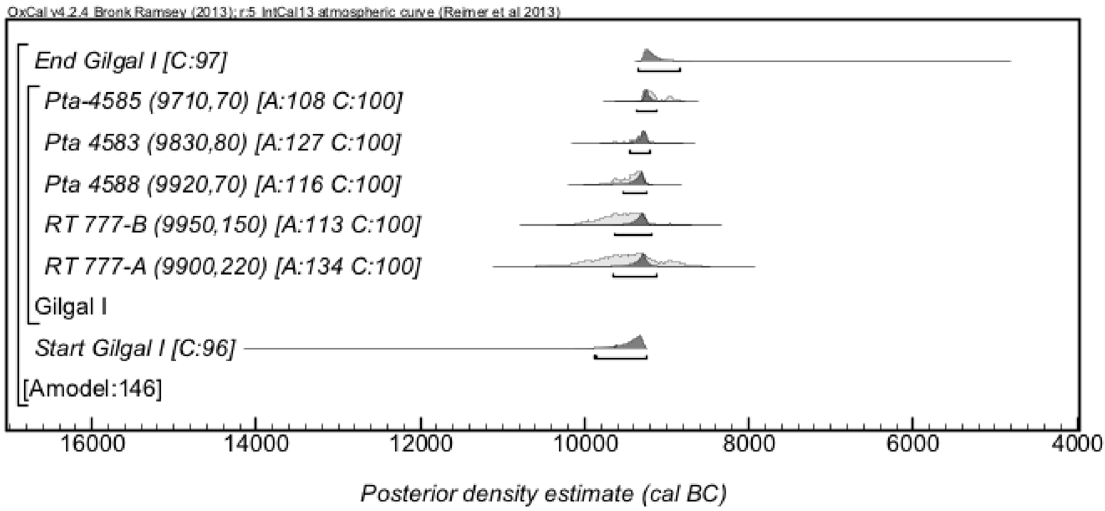


Figure 7.4. Modelled posterior density estimates for Gilgal I.

Previous population estimates

The population of Gilgal I has previously been estimated at 90 people based on a density coefficient of 90 people per hectare and a suggested average PPNA settlement size of one hectare (Kuijt 2008a). An alternative estimate of between 90 and 294 people was based on density coefficients of 90 and 294 people per hectare and an estimated total site extent of one hectare for Gilgal I specifically (Kuijt 2000). A third estimate of 332 people was based on the mean population estimate for the largest five PPNA settlements and a density coefficient of 294 people per hectare (Kuijt 2000).

Population estimates and group size thresholds

The SPF indicates a total (adult) population of around 155 to 285 people, around 2.3 to 4.7 people per dwelling, around 2.3 m^2 to 4.2 m^2 residential floor area per person and around 390 to 720 people per hectare (Table 7.5; Figure 7.5). The population estimate is a considerable revision of the pre-existing estimate range (90-332 people). The estimate exceeds hypothesised group size thresholds relating to the transition to sedentary communities ($P \geq 25$); and the adoption of farming practices ($P \geq 50$), which is evident at Gilgal I by the cultivation of wild barley. Despite the population estimate exceeding the minimum hypothesised threshold for transition to agro-pastoralist subsistence strategies ($P \geq 100$), there is no evidence for domesticated species at Gilgal I. The abundant water availability in this region and the plentiful wild animal, plant and aquatic resources may have mitigated the need for this transition despite the relatively large population size (Bar-Yosef *et al.* 1991).

When groups reach around 150 people, processes of fission and fusion are often initiated to reduce scalar stress (i.e. intra-village conflict). The presence of smaller nearby PPNA settlements (Gilgal III and IV) could reflect fission of Gilgal I into smaller 'daughter villages' in a process similar to that described by Bandy (2004; 2006). Attempts to promote social cohesion may be evidenced by the potential sectoring of the community into household economic units; more formalised ritual practices, including the distinct rectilinear structure identified as non-residential; and the increased amount of built area for non-domestic activities. These developments could reflect the initial transition from a predominantly egalitarian to a more hierarchical community hypothesised to occur in higher populations of at least 350 people.

Table 7.5. Summary of estimates for Gilgal I.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings: 67.08	*Based on total contemporaneous residential floor area (m^2): 663.16*	*Based on total site extent (ha): 0.4*
HUM	201.25-536.66	3-8	1.24-3.30	503.13-1341.65
RADC	132.63-374.67	1.98-5.59	1.77-5.00	331.58-936.67
SPF1	156.86-286.93	2.34-4.28	2.31-4.23	392.14-717.33
SPF2[a]	-	2.79-4.66	-	-
AGF1[a]	-	-	6.13-6.74	-
SPDC	36-117.60	0.54-1.75	5.64-18.42	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (286.93)	*Moderate (189.38)*	*Maximum (156.86)*
Naroll's (1962) AGF1		13.63	19.35	22.67
Wiessner's (1974) AGF2	Open settlements	0.05	0.11	0.16
	Village settlements	13.94	21.12	25.50
	Urban settlements	91.93	121.27	137.51

Additional demographic data			
			Contemporaneous (60%)
Proportion (%) of assessable area comprising:	Built area	51.39	30.83
	Residential built area	34.94	20.97
	Built floor area[b]	40.01	24.01
	Residential floor area	27.63	16.58
Proportion (%) of assessable built area comprising:	Residential built area	68.00	
	Built floor area[c]	77.86	
	Residential floor area	53.77	
Proportion (%) of built floor area comprising residential floor area		69.10	
Mean residential floor area of complete dwellings (m^2)		12.77	

[b] Based on assessable area (214.66 m^2) and built floor area (85.89 m^2).

[c] Based on assessable built area (110.31 m^2) and built floor area (85.89 m^2).

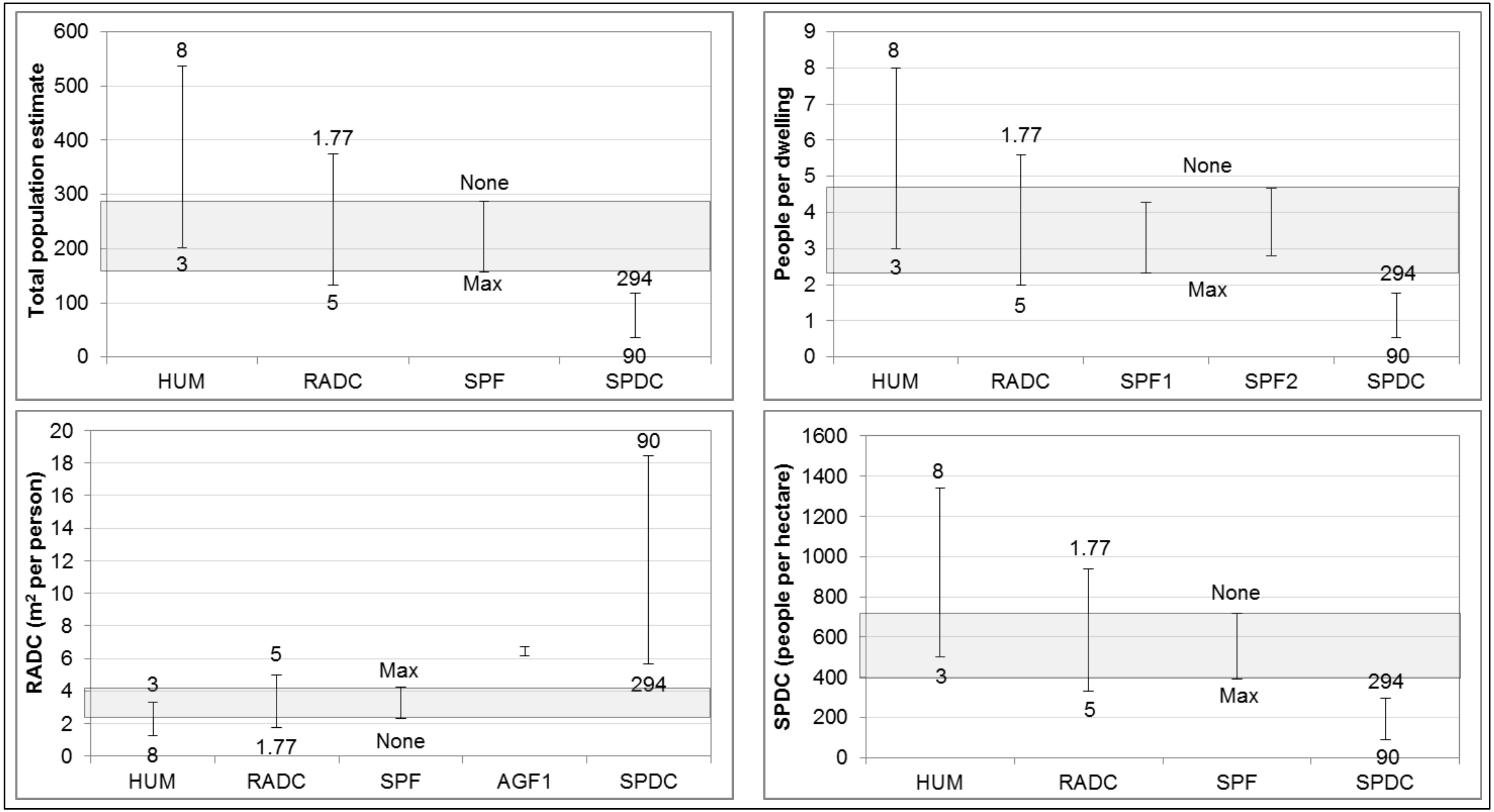


Figure 7.5. Summary of estimates for Gilgal I.

7.1.3 Netiv Hagdud

Site description

Netiv Hagdud is a PPNA village situated near to what was once a substantial spring and lake in the Lower Jordan Valley (Table 7.6; Figure 7.6) (Bar-Yosef *et al.* 1991, p.418). Hemsley (2008, p.163) produced site plans for four phases. ‘Phase I’, which appears to have been the major building phase, was selected for analysis in this investigation. The total estimated site extent of 1.5 hectares for Netiv Hagdud incorporates all phases. A reduced total site extent of half this (0.75 ha) is suggested in this investigation for Phase I, as it is assumed that structures would have been dispersed further across the site as the duration of occupation increased.

Excavations in the southwest portion of the site and a deep sounding in the north revealed numerous curvilinear structures interpreted as “houses” and “storage facilities” (Bar-Yosef *et al.* 1991, p.405). Building density appears similar in both the excavated and deep sounded areas indicating that there may have been relatively continuous habitation across the site (Bar-Yosef *et al.* 1991, p.408). Subsistence evidence indicates that the site was occupied for at least nine months per year (Bar-Yosef *et al.* 1991, p.405).

At least six structures were uncovered (Loci 8-10, 20, 22 and 30) (Bar-Yosef *et al.* 1980; 1991; Bar-Yosef and Gopher 1997; Hemsley 2008). The presence of hearths, stone bowls and embedded cup-hole mortars reflects household-based food-related activities (i.e. processing and consumption) potentially indicative of the emerging economic independence of these household units (Rosenberg 2008, p.29). Loci 8 and 10 contained internal partitioning, indicating compartmentalisation of activities within structures. Locus 10 contained an oval-shaped concave cobble hearth feature (c. 1 m diameter) similar to features found in Loci 8 and 22 (Bar-Yosef *et al.* 1991). Burial remains were associated with Locus 22 and, perhaps, Locus 10. The location of a skull cache and high proportions of pestles and grinders within Locus 8, may indicate an additional special function for this building (Bar-Yosef and Gopher 1997). Locus 8 also contained cup-marked stone slabs, a rectangular cobble-covered installation (c. 1 m long), mortars, bowls, polished flat pebbles and a flint axe. Despite the evidence for additional non-domestic activities in Locus 8, all structures are interpreted as potential residential areas (Bar-Yosef *et al.* 1991, p.408).

Table 7.6. Description of Netiv Hagdud Phase I* and refined variables.

Estimated site extent		7,500 m^2
Assessable area		533.82 m^2
Potential dwellings		6
Environment		On slope above Wadi Bakar; perennial watercourse; substantial spring and lake nearby
Subsistence		Hunting, gathering, cultivation (wild barley and lentils: one of the earliest farming communities; sickle blades)
Architecture		Curvilinear; organised in clusters; semi-subterranean; thick stone walls; organic roofing; moderate sub-divisioning or compartmentalisation; moderate remodelling, superpositioning and abandonment
Economy		Dwelling-based processing and consumption (vessels, cup hole mortars, hearths); secondary station for obsidian distribution (Anatolian obsidian); craft specialisation (figurines, decorative items and items of personal adornment)
Ritual/community organisation		Established ritual (burials and adult skull removal); symbolic items (incised pebbles, polished pebbles, female figurines, decorative objects); social differentiation/social status (items of personal adornment)
Structural contemporaneity		60%
Refined variables:	SPF	Moderate-maximum (none excluded based on no evidence for separate permanent storage structures; probable storage within residential floor area)
	AGF2	Open and village

* Bar-Yosef *et al.* 1980; 1991; Bar-Yosef and Gopher 1997; Colledge 2001; Weiss *et al.* 2006; Hemsley 2008.

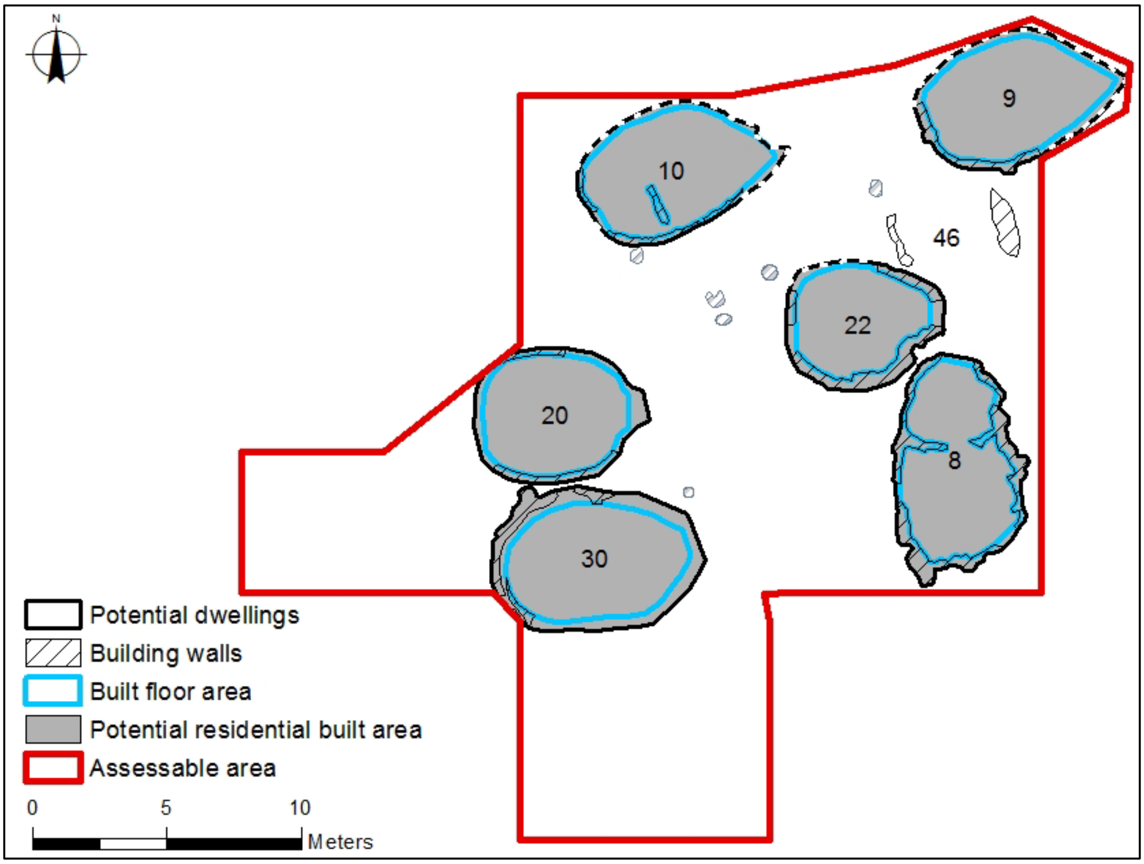


Figure 7.6. Site plan of Netiv Hagdud Phase I (transcribed from Bar-Yosef *et al.* 1980, p.203; 1991, pp.407 and 409; Hemsley 2008, p.175).

Contemporaneity assessment

The majority of structures comprise relatively thin stone and mudbrick walls and organic roofing, with variable evidence for remodelling and maintenance (Bar-Yosef *et al.* 1980). Analysis of comparable earthen/masonry structures with moderate maintenance generally indicates a use life of between 35 and 55 years (see Table 5.7).

Sufficient radiocarbon dates exist for Bayesian chronological modelling of phase length and building use-life. Dateable material was collected from an area of deep sounding across three main levels (i.e. lower, middle and upper complex) (Figure 7.7). Although a lack of chronostratigraphic order of dates even within the same structure (i.e. Locus 1001) revealed potentially residual and/or intrusive dates, a χ^2 test (df = 10, T = 8.0 (5% 18.3)) indicated that all dates conform to the same stratigraphic sequence.

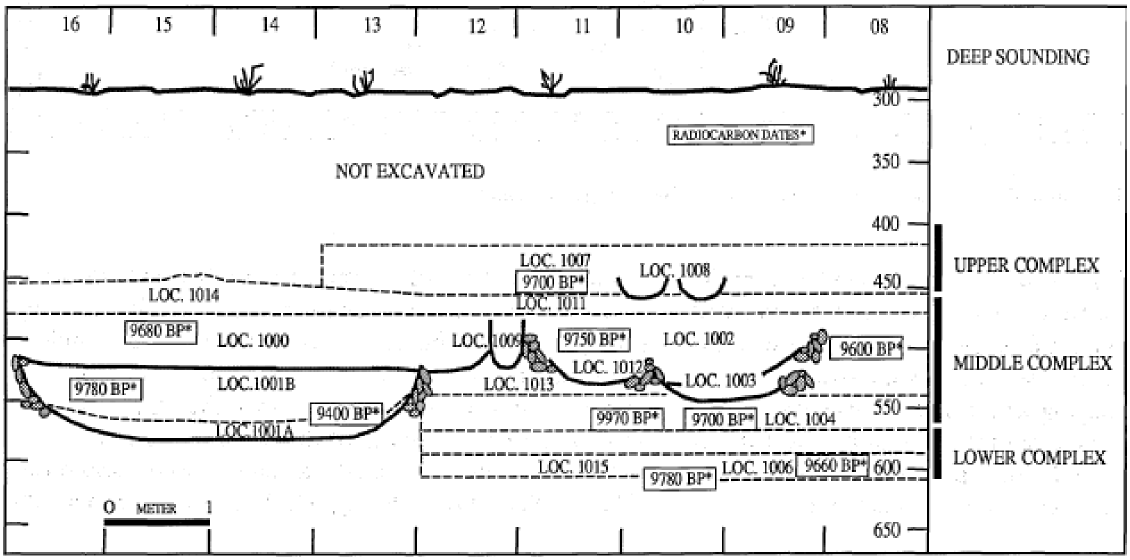


Figure 7.7. Schematic section of deep sounding at Netiv Hagdud, indicating the context of radiocarbon dates (uncalibrated BP) (Bar-Yosef *et al.* 1991, p.408).

There does not appear to be any major period of abandonment between the lower, middle and upper complexes (Bar-Yosef *et al.* 1991, p.421). As such, the chronological model was constructed to represent three contiguous phases (lower, middle and upper). Within these phases, individual building phase models were constructed for buildings with more than one date (lower complex: Locus 1006; middle complex: Loci 1001 and 1004), with all other dates placed within a separate phase model. The use of building phase models allows overlap between the dates of the structures.

Chronological modelling highlighted two dates with poor agreement (RT 762D: A = 53.8; RT 762C: A = 20.9) (Table 7.7; Figure 7.8). These dates were removed from a subsequent run of the model. The first model produced estimates of middle complex phase length and building use-life that could be used to reconstruct a contemporaneity value despite the relatively long length of these estimates. Although the final model prevented useful span estimates for building use-life, it produced potentially more realistic phase length estimates for the phases with more than one date (i.e. lower and middle complex).

The final model indicated a start date of *9,410 to 8,930 cal BC* and an end date of 9,260 to 8,880 cal BC, with a total span of up to 480 years. This compares well with previous estimates of the occupation span by Bar-Yosef *et al.* (1991, p.407) and Hemsley (2008, p.160) (350-550 years). Transition dates of *9,290 to 8,940 cal BC* between the lower and middle complexes and *9,260 to 8,860 cal BC* between the middle and upper complexes produced span estimates of up to 80 years each for the lower and middle complexes; and up to 10 years for the upper complex.

Contemporaneity values were reconstructed based on the upper end of the 95.4% probability range of (1) middle complex span estimates derived from the initial model for phase length (220 years) and building use-life (120-130 years) (contemporaneity value: 54.55-59.09%); and (2) lower and middle complex phase span estimates derived from the final model (80 years) and building use-life estimates of comparable structures derived from archaeological, ethnographic and experimental research (35-55 years) (contemporaneity value: 43.75-68.75%). Based on these estimates, an average contemporaneity value of 60% is utilised for Netiv Hagdud.

Previous population estimates

The population of Netiv Hagdud has previously been estimated at 90 people based on 90 people per hectare and a suggested average total site extent of one hectare for PPNA settlements (Kuijt 2008a). An alternative estimate of between 135 and 441 people was based on 90 and 294 people per hectare and estimated total site extent of 1.5 hectares (Kuijt 2000). A third estimate of 332 people was based on the population estimate derived for the largest five PPNA settlements (Kuijt 2000). In addition, Goring-Morris and Belfer-Cohen (2011, S201) suggest that Netiv Hagdud “may have housed up to a couple of hundred inhabitants”.

Table 7.7. Modelled boundary dates and span estimates for Netiv Hagdud. Dates with poor agreement (A ≤ 60%) highlighted in grey.

Locus	**Complex**	**Lab reference**	**Material**	**Radiocarbon date (BP)**	**Radiocarbon date range (cal BC) (95%)**	**1st run** Posterior density estimate range (cal BC) (95.4%)	**1st run** Indices *Amodel=86.2* *Aoverall=88.2* *A*	*C*	**2nd run** Posterior density estimate range (cal BC) (95.4%)	**2nd run** Indices *Amodel=212.4* *Aoverall=206.8* *A*	*C*
Start Lower Complex						*9600-8960*		*95.8*	*9410-8930*		*72.5*
1006	Lower	RT 762F	CH	9780 ± 150	9390-8820	9410-8960	162.1	99.3	9330-8930	160.4	79.3
	Lower	Pta 4556	CH	9660 ± 70	9300-8820	9310-8960	85.8	99.5	9300-8950	100.3	81.5
	Span Locus 1006					**0-140**		**99.9**	**0-80**		**99.5**
Span Lower Complex						**0-140**		**99.9**	**0-80**		**99.5**
Transition Lower/Middle Complex						*9300-8950*		*99.6*	*9290-8940*		*82.4*
1001	Middle	Pta 4557	CH	9780 ± 90	10120-9180	9280-8920	100.9	99.7	9270-8930	108.7	82.1
	Middle	RT 762D	CH	9400 ± 180	9660-8630	9270-8930	53.8	99.7			
	Span Locus 1001					**0-130**		**100**			
1004	Middle	RT 762C	CH	9970 ± 150	9650-8830	9290-8920	20.9	99.7			
	Middle	OxA 744	S	9700 ± 150	9220-8290	9280-8920	139.4	99.8	9280-8920	142.9	81.4
	Span Locus 1004					**0-120**		**100**			
1000	Middle	RT 762A	CH	9680 ± 140	10570-8270	9280-8920	132.1	99.7	9280-8920	134.3	81.6
1012	Middle	Pta 4555	CH	9750 ± 90	9800-8760	9280-8920	124.1	99.7	9270-8930	133.3	81.9
1002	Middle	RT 762B	CH	9600 ± 170	9450-8470	9270-8920	113.9	99.7	9280-8920	111.1	81.5
?	Middle	RT 502A	CH	9730 ± 380	9450-8630	9280-8920	141	99.8	9280-8920	142.1	81.5
Span Middle Complex						**0-220**		**99.9**	**0-80**		**97.4**
Transition Middle/Upper Complex						*9260-8860*		*99.5*	*9270-8910*		*81.1*
1007	Upper	Pta 4590	CH	9700 ± 80	9260-8820	9250-8840	113.6	99.3	9260-8860	125.2	79.4
Span Upper Complex						**0-280**		**99.8**	**0-10**		**100**
End Upper Complex						*9250-8810*		*98.7*	*9260-8800*		*78.3*
Span Lower-Upper Complex						**0-580**		**97.5**	**0-480**		**83.2**

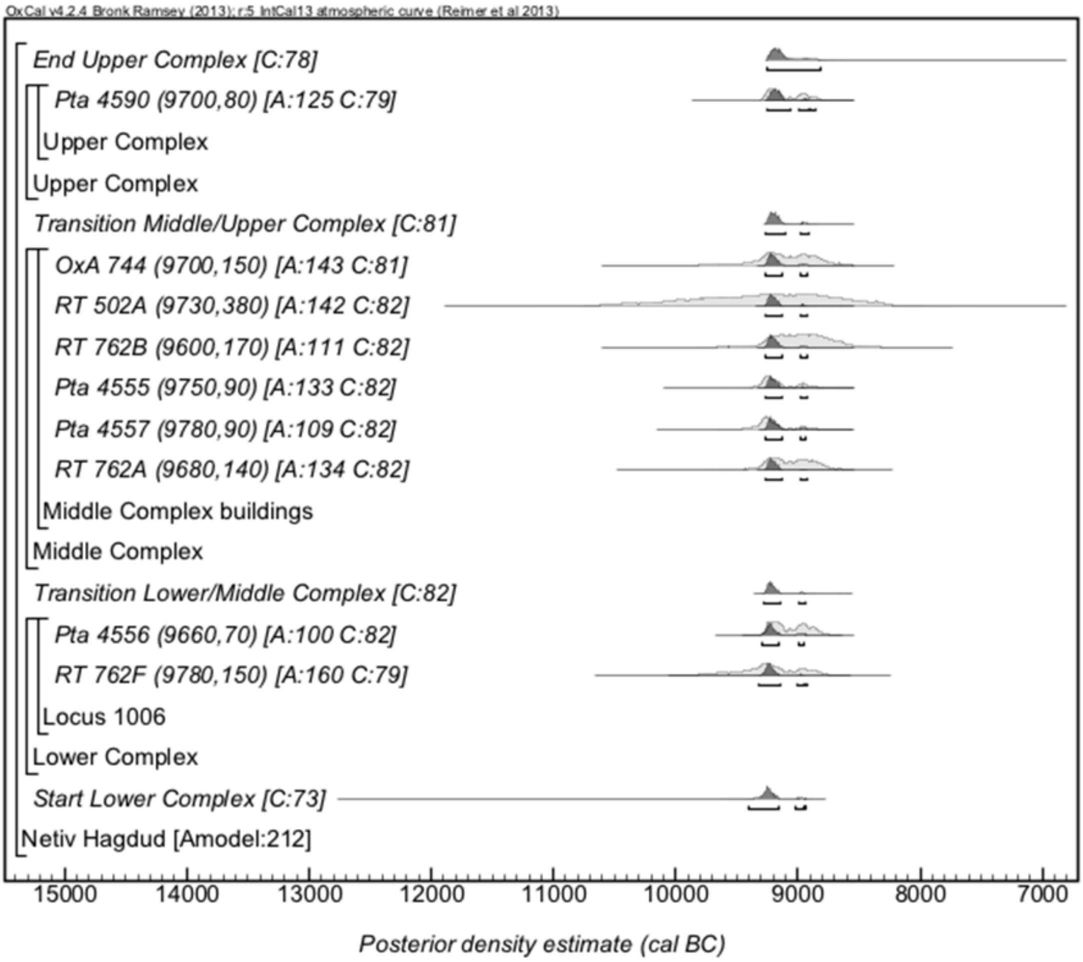


Figure 7.8. Modelled posterior density estimates for Netiv Hagdud (2nd run: divergent dates removed).

Population estimates and group size thresholds

The SPF based on moderate and maximum storage provisions indicates a total (adult) population of around 215 to 270 people, around 4.2 to 5.3 people per dwelling, around four m^2 to five m^2 residential floor area per person and around 290 to 360 people per hectare (Table 7.8; Figure 7.9). The population estimate is a considerable refinement of the pre-existing estimate range (90-441 people). The estimate exceeds the hypothesised group size thresholds relating to the transition to sedentism (P ≥ 25); the adoption of farming practices (P ≥ 50); and the minimum threshold for the transition to an agro-pastoralist subsistence strategy (P ≥ 100). Evidence suggests that Netiv Hagdud was one of the earliest farming communities, though there is no evidence for domesticated species (Bar-Yosef *et al.* 1991).

The population estimate also exceeds the threshold for the introduction of mechanisms for creating social cohesion within larger groups (P ≥ 150), which may be evidenced by more formalised ritual activities and potential sectoring into household economic units (Rosenberg 2008). As the population of Netiv Hagdud began to exceed this threshold, it is possible that some inhabitants migrated to other areas, forming settlements of a more manageable size (Bandy 2004; 2006). Indeed, Netiv Hagdud lies in close proximity to Gilgal I and other smaller PPNA settlements in the Salibiya Basin, which may have initiated in this way. These developments, in addition to evidence for specialist craft production, an organised exchange network relating to obsidian distribution, and numerous items of personal adornment possibly related to individual or group identification (Bar-Yosef *et al.* 1991) indicate that the inhabitants of Netiv Hagdud were transitioning from a predominantly egalitarian to more hierarchical community, previously suggested to occur in settlements of higher populations ($P \geq 350$).

Table 7.8. Summary of estimates for Netiv Hagdud Phase I.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings: 50.58	*Based on total contemporaneous residential floor area (m^2): 1078.93*	*Based on total site extent (ha): 0.75*
HUM	151.74-404.63	3-8	2.67-7.11	202.32-539.51
RADC	215.79-609.57	4.27-12.05	1.77-5.00	287.71-812.75
SPF1	214.6-268.12	4.24-5.3	4.02-5.03	286.13-357.49
SPF2[a]	-	4.42-5.32	-	-
AGF1[a]	-	-	8.97-9.29	-
SPDC	67.5-220.5	1.33-4.36	4.89-15.98	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:** *None (415.85)*	*Moderate (268.12)*	*Maximum (214.6)*
Naroll's (1962) AGF1		11.22	16.23	19.58
Wiessner's (1974) AGF2	Open settlements	0.04	0.10	0.16
	Village settlements	18.04	27.97	34.95
	Urban settlements	134.59	180.34	209.20

Additional demographic data			*Contemporaneous (60%)*
Proportion (%) of assessable area comprising:	Built area	31.70	19.02
	Residential built area	31.70	19.02
	Built floor area [b]	23.98	14.39
	Residential floor area	23.98	14.39
Proportion (%) of assessable built area comprising:	Residential built area	100.00	
	Built floor area [c]	75.63	
	Residential floor area	75.63	
Proportion (%) of built floor area comprising residential floor area		100.00	
Mean residential floor area of complete dwellings (m^2)		21.33	

[b] Based on assessable area (533.82 m^2) and built floor area (127.99 m^2).
[c] Based on assessable built area (169.23 m^2) and built floor area (127.99 m^2).

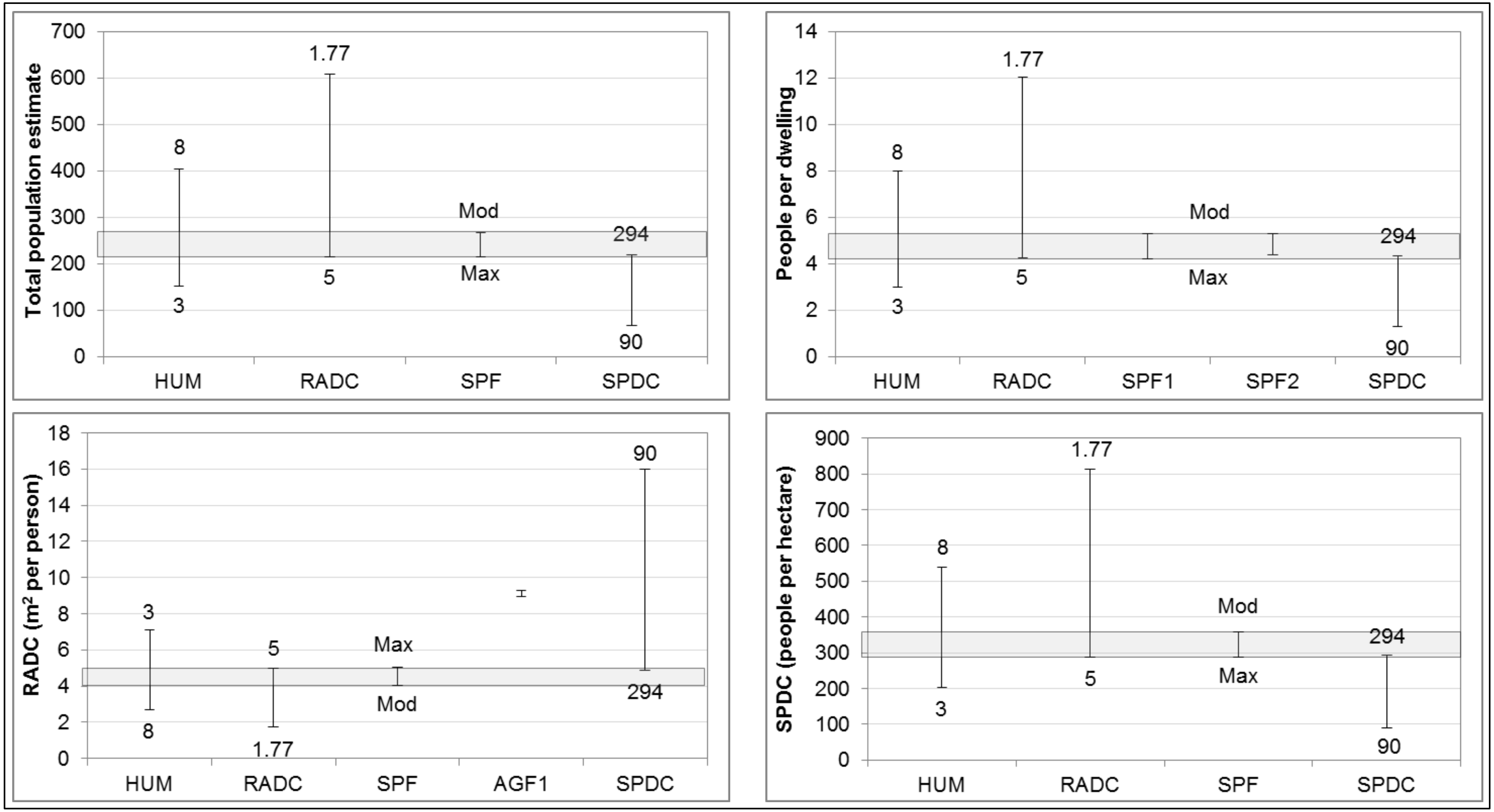


Figure 7.9. Summary of estimates for Netiv Hagdud Phase I.

7.1.4 El-Hemmeh (PPNA)

El-Hemmeh is a multi-period PPN settlement in Jordan. Two main phases were identified, with the majority of structures relating to the PPNA and LPPNB (Makarewicz *et al.* 2006). These phases are described and assessed separately (see Section 7.19 for LPPNB el-Hemmeh).

Site description

Excavations of the earlier PPN occupation exposed 12 semi-subterranean, curvilinear structures, with light organic roofing, often with two-course stone walls set in mud mortar and occasionally with a pisé superstructure (Table 7.9; Figure 7.10). A further two centrally-located structures appear to be communal hearths or storage pits. Bar-Yosef (1998) suggests that the earlier PPN occupation at el-Hemmeh, which comprised a cluster of small structures, was inhabited by one extended family unit.

Stratigraphic analysis revealed at least three earlier PPN subphases spanning the second half of the PPNA period and possibly extending into the EPPNB. Structural composition and the relationship between structures were assessed in detail to identify potential PPNA structures for inclusion in the micro-level assessment. A single radiocarbon date of 9,450 ± 60 BP (9,130-8,570 cal BC) obtained from a hearth in Structure 1 places this structure within the second half of the PPNA (Makarewicz *et al.* 2006, p.215). At least five other structures (2-3, 5, 10 and 12) were also assigned to the PPNA by Makarewicz *et al.* (2006). The remainder of the structures (4-8) have been assigned to periods in this investigation based on stratigraphic evidence and archaeological features (Makarewicz and Rose 2011, pp.24-28). Structures assigned to the PPNA include Structure 4, which is of similar architectural construction to Structures 2 and 3; Structure 8, which shares a common wall with Structure 2; and Structure 5, which is considered to have had an extended use-life potentially spanning much of the earlier PPN occupation and possibly utilised through to the EPPNB. The remainder of structures are suggested to date to the EPPNB. These include Structure 6, which cuts into the later construction elements of Structure 5; and Structure 7, both of which have superior architectural construction and unique interior finds, including three complete single human burials within well-constructed cists in Structure 6 and a solid partitioning wall in Structure 7 delineating a large subterranean bin feature (Structure 11). Based on this assessment, structures assigned to the PPNA phase assessed in this investigation include Structures 1 to 5, 8 and 10. Structure 12 lies beneath structures assigned to this phase and is, thus, not included in this investigation (Makarewicz and Rose 2011; White and Makarewicz 2012).

Structures 1 to 4 and 10 demonstrate sufficient evidence for interpretation as dwellings. Structures identified as dwellings contain hearths, raised circular platforms, occasional storage bin features, and domestic artefacts including pestles, a cup, a bone spatula and a clay ball. The original form of Structure 5 is also interpreted as a domestic structure. Remodelling and addition of walls connected the northern border of Structure 5 to later PPNA/EPPNB Structure 6, potentially indicate an EPPNB date for this remodelling. Therefore, only the original boundaries of Structure 5 are included in this analysis.

Structure 8 appears to have maintained a non-residential function based on a lack of internal features, a unique wall break allowing entrance through the side and the presence of thin and delicate flooring with red and orange discolouration, probably resulting from informal hearths (Makarewicz and Rose 2011, p.28).

Table 7.9. Description of PPNA el-Hemmeh* and refined variables.

Estimated site extent		1,000 m^2
Assessable area		61.49 m^2
Potential dwellings		6
Environment		On an alluvial fan near perennial watercourse in steep-sided Wadi Hasa
Subsistence		Hunting, gathering, cultivation (wild barley); some storage within dwellings
Architecture		Curvilinear; organised in clusters; semi-subterranean; thick stone walls; organic roofing; no/very few subdivisions or compartmentalisation; some remodelling and superpositioning
Economy		Some dwelling-based storage, processing and cooking (storage features, hearths, vessels, grinding implements); communal processing and cooking (hearths in open areas); possible incipient craft specialisation (figurine, polished stone axe)
Ritual/community organisation		Incipient ritual activity: human burials in floor deposits, figurine, polished axe and potential ritual structure
Structural contemporaneity		75%
Refined variables:	HUM	Minimum (average and maximum nuclear family sizes excluded based on insufficient mean residential floor area (4.83 m^2))
	AGF2	Open and village

* Wright 2000; Makarewicz and Austin 2006; Makarewicz *et al.* 2006; Makarewicz and Rose 2011; White and Makarewicz 2012; White and Wolff 2012; White 2013.

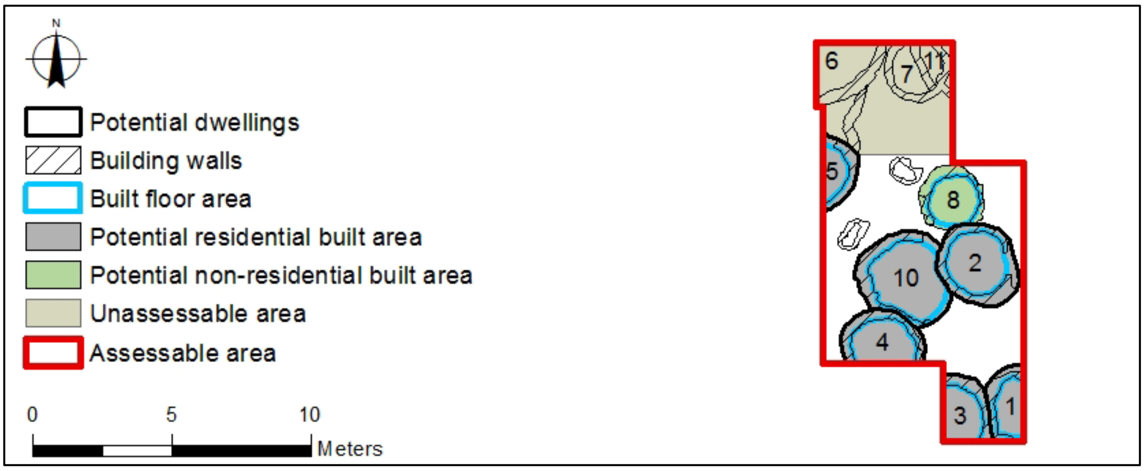


Figure 7.10. Site plan of PPNA el-Hemmeh (transcribed from Makarewicz and Rose 2011, p.24)

Contemporaneity assessment

All dwellings exhibit successive flooring events interspersed with layers of pisé melt, indicating periods of temporary disuse followed by reoccupation (Makarewicz and Rose 2011, p.25). Structures 2 and 3 exhibit at least 10 and five flooring events, respectively. Structure 2 also displays evidence for remodelling. Archaeological, ethnographic and experimental research of comparable structures (earthen/masonry with moderate-considerable maintenance) indicate a potential use-life of between 35 and 75 years (see Table 5.7).

There are insufficient radiocarbon dates for chronological modelling of phase length and building use-life. Therefore, a contemporaneity value could not be directly derived for PPNA el-Hemmeh. The most comparable sites for which precise contemporaneity values have been reconstructed are Beidha Subphases A1 (71.43%) and A2 (75%), and Shkārat Msaied (80%). Based on these, an average contemporaneity value of 75% is utilised for PPNA el-Hemmeh.

Population estimates and group size thresholds

The SPF indicates a total (adult) population of around 70 to 100 people, around 0.9 to 1.5 people per dwelling, around 2.3 m^2 to 3.3 m^2 residential floor area per person and around 690 to 1,010 people per hectare (Table 7.10; Figure 7.11). The population estimate exceeds the hypothesised group size thresholds relating to the transition to sedentism ($P \geq 25$) and the adoption of farming practices ($P \geq 50$). There is evidence for storage within some structures, which has been linked to sedentism, and for the cultivation of wild barley (White 2013).

There is also evidence for ritual activity that may reflect attempts to promote social cohesion, which is expected to occur within larger populations ($P \geq 150$). The presence of imported materials may indicate that PPNA el-Hemmeh formed part of a broader social network with other sites in the region, which could explain the presence of more developed processes at this settlement despite its low estimated population size.

Table 7.10. Summary of estimates for PPNA el-Hemmeh.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 73.18	*Based on total contemporaneous residential floor area (m^2): 227.31*	*Based on total site extent (ha): 0.1*
HUM	219.55	3	1.04	2195.48
RADC	45.46-128.42	0.62-1.75	1.77-5.00	454.62-1284.23
SPF1	68.62-100.62	0.94-1.37	2.26-3.31	686.06-1006.19
SPF2[a]	-	1.23-1.53	-	-
AGF1[a]	-	-	8.19-8.72	-
SPDC	9-29.4	0.12-0.4	7.73-25.26	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage: None (100.62)	Moderate (73.19)	Maximum (68.61)
Naroll's (1962) AGF1		7.12	9.31	9.83
Wiessner's (1974) AGF2	Open settlements	0.10	0.19	0.21
	Village settlements	9.94	13.66	14.58
	Urban settlements	46.22	57.15	59.66

Additional demographic data			Contemporaneous (75%)
Proportion (%) of assessable area comprising:	Built area	54.72	41.04
	Residential built area	47.83	35.87
	Built floor area [b]	34.57	25.93
	Residential floor area	30.31	22.73
Proportion (%) of assessable built area comprising:	Residential built area	87.41	
	Built floor area [c]	63.18	
	Residential floor area	55.38	
Proportion (%) of built floor area comprising residential floor area		87.66	
Mean residential floor area of complete dwellings (m^2)		4.83	

[b] Based on assessable area (61.49 m^2) and built floor area (21.26 m^2).
[c] Based on assessable built area (33.65 m^2) and built floor area (21.26 m^2).

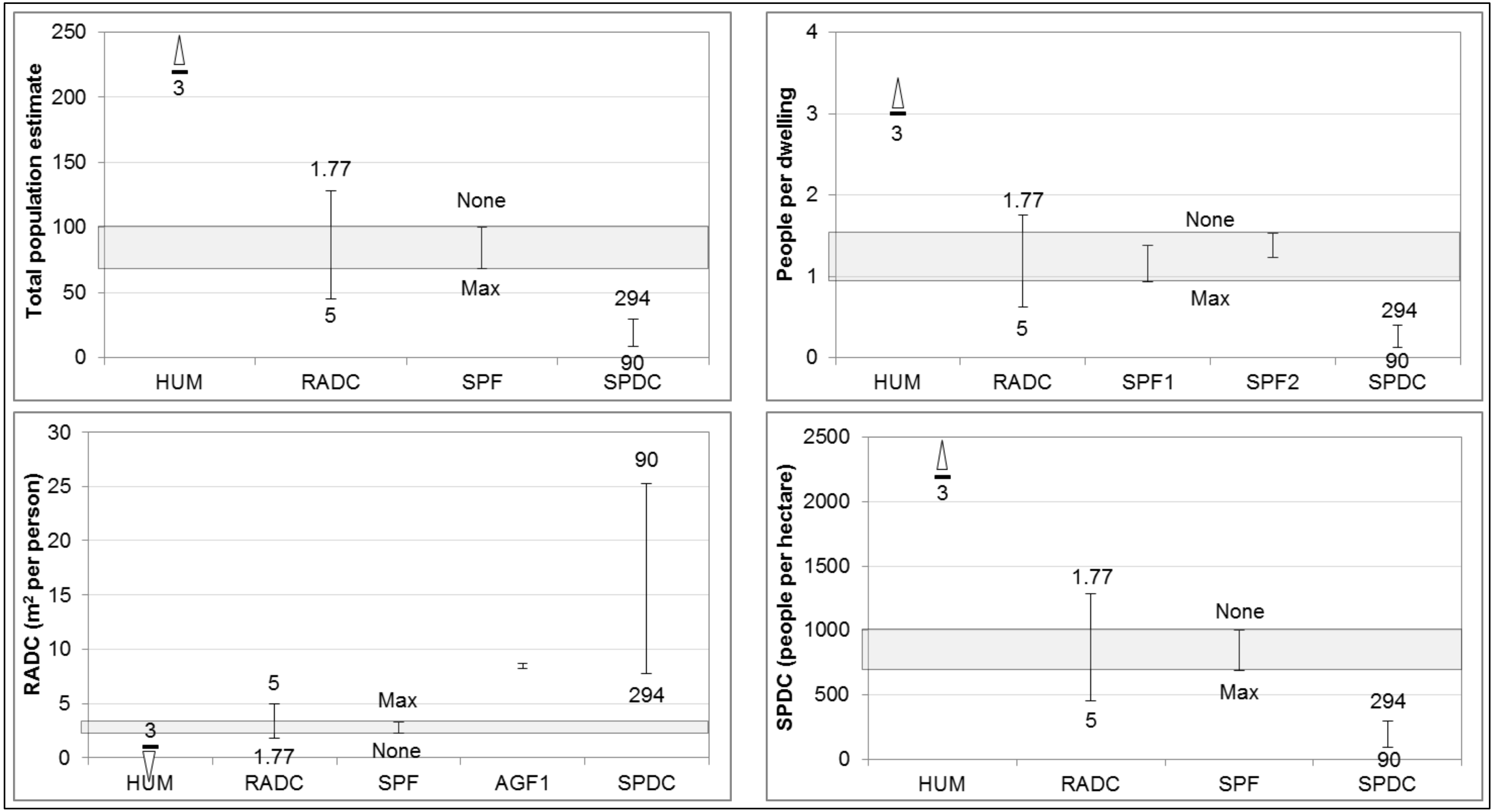


Figure 7.11. Summary of estimates for PPNA el-Hemmeh.

7.1.5 Shkārat Msaied

Site description

Shkārat Msaied is a MPPNB village in southern Jordan. Investigations identified at least five phases, with the majority of building and remodelling occurring in Phase II (Kinzel 2013). Micro-level analysis is conducted on the Phase II occupation (Table 7.11; Figure 7.12). The extent of the occupation is unclear. However, a site extent of 0.2 hectares is proposed based on the presence of around 0.1 hectares of well-preserved architecture; topographical restriction due to a wadi bordering the north-eastern boundary of the site; and the size of comparable MPPNB sites in the region.

Excavations exposed at least 16 Phase II curvilinear structures arranged in clusters. Several potential domestic structures (Units A-E, L, R and T) have been identified (Jensen *et al.* 2005; Hermansen *et al.* 2006). The walls of these structures predominantly comprise limestone foundations and a double course of sandstone around 60 cm wide or more supported by a series of wooden beams placed at regular intervals around the inside of the stone wall. Wall interiors were occasionally finished with upright standing stone slabs (Units A-C). Floors were plastered and usually re-plastered, and in at least one case (Unit C) had been painted red. Most structures were identified as domestic based on the presence of hearths. Several contained stone installations or cists to the east of the entrance, with Units B, C and D containing a stone platform on the wall opposite the entrance. Evidence suggests that roofs were constructed with wooden beams, mud mortar, soil and small stones, forming a flat surface that may have been utilised as an activity platform or floor of an upper storey.

Through comparison with these residential structures, five additional units (H-K, X and Y) are assigned as potential dwellings in this investigation. Unit J was originally interpreted as a communal cereal processing centre based on the large quantity of grinding implements (Jensen *et al.* 2005). However, physical inspection in 2015 highlighted notable similarities to the other suggested domestic structures and, as such, Unit J was also considered potential residential area in this investigation.

Table 7.11. Description of Shkārat Msaied Phase II * and refined variables.

Estimated site extent	2,000 m^2
Assessable area	679.91 m^2
Potential dwellings	13
Environment	On slope on sandstone mountain above wadi
Subsistence	Hunting, gathering, cultivation (cereal; grinding stones; picks), pastoralism (possibly domesticated goat and sheep); storage in dwellings (some measured independently of floor area); probable additional on-floor storage
Architecture	Curvilinear; organised in clusters; semi-subterranean and on terraces; thick stone walls with wooden posts; plastered walls and floors; organic roofing; flat roofs possibly utilised for storage or activities; partitioning; considerable compartmentalisation; considerable remodelling; potential sectoring of dwelling clusters
Economy	Dwelling-based storage, processing and consumption (storage and hearths within dwellings); possible communal processing (Unit J); craft specialisation (bead workshops: Units A and B; figurines; naviform cores; worked shell, bone and other material); trade (obsidian; mother of pearl); incised stones/seals
Ritual/community organisation	Established ritual and organisation (Unit F – mortuary building, central location, large size, large raised-rimmed hearth, numerous annexed structures, two stone benches creating a rectangular interior plan, at least 15 inhumations in stone cists; bone figurine; incised stones and slabs; ritual feasting - animal remains with burials; celts; shell and bone beads); potential household-based ritual (stone cists); social differentiation/hierarchy (items of personal adornment; differing structural associations)
Structural contemporaneity	80%
Refined AGF2 variables:	Open and village

* Byrd 1994; Hermansen and Hoffman Jensen 2002; Bartl *et al.* 2006; Jensen *et al.* 2005; Hermansen *et al.* 2006; Edwards 2007; Kinzel 2013.

Figure 7.12. Site plan of structures built and/or (probably) utilised during Phase II at Shkārat Msaied (transcribed from Kinzel 2013, p.339).

Contemporaneity assessment

Considerable evidence exists for building maintenance, re-plastering, remodelling and subdivision (Jensen *et al.* 2005). Archaeological, ethnographic and experimental research of comparable structures indicates potential use-life of 35 to 75 years (see Table 5.7). The structures demonstrate considerable comparability to those of Beidha Phases A and B. Use-life estimates for Beidha range from 50 to 100 years, with contemporaneity values ranging from 71.43% to 75%.

There are a sufficient number of radiocarbon determinations for Shkārat Msaied to enable Bayesian chronological modelling. Of the five available dates, one is considerably older (Aar-936: 9590 ± 90 BP) and was removed prior to analysis. Of the four remaining dates, three were sourced from Unit E, which appears to have been occupied in at least three phases (Phases I-III). A χ^2 test (df = 13, T = 12.001 (5% 7.8)) indicated that at least one date does not conform to the stratigraphic sequence. This suggests that more than one phase is present. Unfortunately, no information regarding phase is supplied. A single 'phase' model was constructed containing individual building phase models for Units C and E to allow for potential overlap between these structures. The model did not highlight any statistical outliers (all agreement values A ≥ 60%) (Table 7.12; Figure 7.13).

The model produced a start date of *8,890 cal BC* and an end date of 7*,450 cal BC*, with an occupation span of up to 520 years. The model produced a span estimate of up to 470 years for Unit E. These span estimates produced a contemporaneity value of 90.39%. Evidence suggests that most structures were built almost contemporaneously and it appears that most or all of the entrances may have been deliberately blocked, indicating simultaneous abandonment (Jensen *et al.* 2005, p.124). This could suggest a high degree of contemporaneity. Therefore, the contemporaneity value based on the modelled span estimates could be reliable, even though the span estimates themselves are clearly too broad for the phase under investigation. However, to avoid inflating estimates, a more conservative contemporaneity value was derived from the prior chronological information regarding the site stratigraphy, the modelled data and contemporaneity values derived for comparative sites (Beidha Phases A and B: 71.43%-75%). A contemporaneity value of 80% is proposed for Shkārat Msaied.

Table 7.12. Modelled boundary dates and span estimates for Shkārat Msaied.

Unit	Lab reference	Material	Context	Radiocarbon date (BP)	Radiocarbon date range (cal BC) (95%)	Posterior density estimate range (cal BC) (95.4%)	Indices *Amodel=114* *Aoverall=113.4*	
							A	*C*
Start Shkārat Msaied						*8890-…*		*98.4*
Unit E	Wk-15160	CH, wood		9144 ± 55	8540-8260	8460-8230	105.2	99.7
	Wk-15159	CH, wood		8977 ± 60	8300-7960	8300-7980	112	99.8
	Aar-9337	CH, Pistacia		8885 ± 70	8250-7760	8280-7910	104.3	99.6
	Span Unit E					**0-470**		**98.9**
Unit C	Aar-9335	CH. Ephedra	In stone cist	8880 ± 80	8260-7750	8290-7880	104.6	99.6
End Shkārat Msaied						*…-7450*		*97.9*
Span Shkārat Msaied						**0-520**		**99**

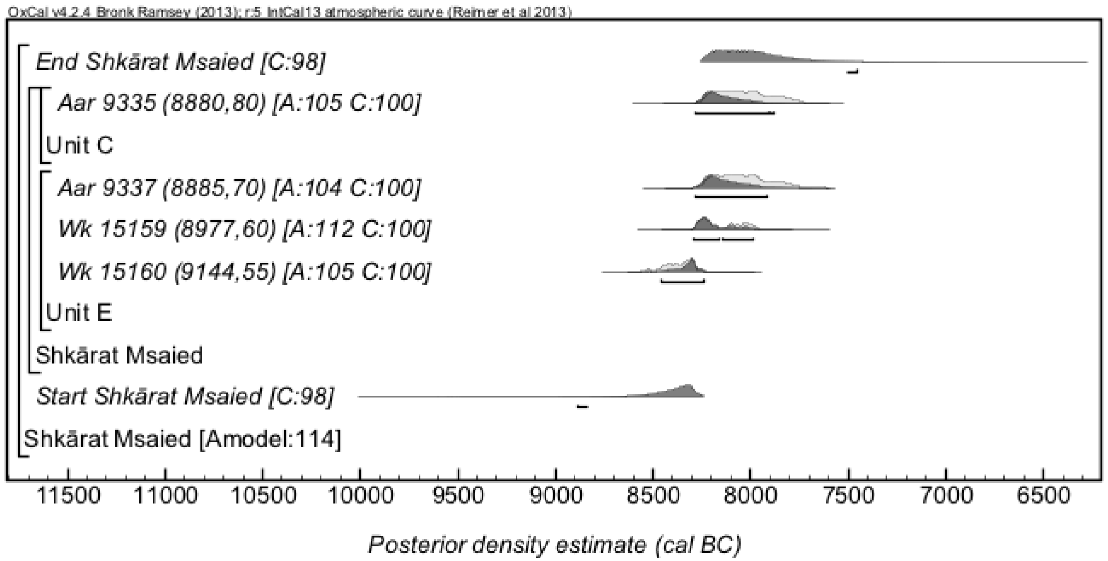


Figure 7.13. Modelled boundary dates and span estimates for Shkārat Msaied.

Population estimates and group size thresholds

The SPF indicates a total (adult) population of around 80 to 150 people, around 2.6 to 4.9 people per dwelling, around 2.5 m^2 to 4.7 m^2 residential floor area per person and around 400 to 740 people per hectare (Table 7.13; Figure 7.14). The population estimate exceeds the hypothesised group size thresholds relating to initial sedentism ($P \geq 25$); the adoption of farming practices ($P \geq 50$); and the minimum threshold for the transition to an agro-pastoralist subsistence strategy ($P \geq 100$). Evidence suggests that the inhabitants of Shkārat Msaied intensively cultivated wild plants and may have cultivated domesticated emmer wheat. In addition, the inhabitants engaged in pastoral practices relating to potentially domesticated goats and sheep (Jensen *et al.* 2005, p.131).

There is evidence for mechanisms to reduce scalar stress and promote social cohesion ($P \geq 150$) and for the transition from more egalitarian to more complex social structure ($P \geq 350$), including craft specialisation, ritual activity and potential household economic units, indicated by dwelling based workshop activities (i.e. bead manufacture in Units A and B; Jensen *et al.* 2005, p.127). The presence of such processes at Shkārat Msaied despite the estimated population being at the lower end of the crucial range may indicate that the village formed part of wider network of sites, which may have included the nearby MPPNB village at Beidha. This is supported by evidence for an extensive trade network relating to marine materials (i.e. mother of pearl and shells) (Jensen *et al.* 2005).

Table 7.13. Summary of estimates for Shkārat Msaied Phase II.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 30.59	*Based on total contemporaneous residential floor area (m^2): 373.81*	*Based on total site extent (ha): 0.2*
HUM	91.78-244.74	3-8	1.53-4.07	458.88-1223.69
RADC	74.76-211.19	2.44-6.9	1.77-5	373.81-1055.97
SPF1	80.44-148.99	2.63-4.87	2.51-4.65	402.2-744.94
SPF2[a]	-	2.92-4.93	-	-
AGF1[a]	-	-	7.8-8.6	-
SPDC	18-58.8	0.59-1.92	6.36-20.77	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage: *None (148.99)*	*Moderate (97.83)*	*Maximum (80.44)*
Naroll's (1962) AGF1		8.72	12.43	14.66
Wiessner's (1974) AGF2	Open settlements	0.09	0.21	0.31
	Village settlements	13.42	20.44	24.86
	Urban settlements	71.15	94.19	107.31

Additional demographic data			*Contemporaneous (80%)*
Proportion (%) of assessable area comprising:	Built area	58.13	46.50
	Residential built area	45.91	36.73
	Built floor area [b]	29.47	23.58
	Residential floor area	23.36	18.69
Proportion (%) of assessable built area comprising:	Residential built area	78.98	
	Built floor area [c]	50.70	
	Residential floor area	40.19	
Proportion (%) of built floor area comprising residential floor area		79.29	
Mean residential floor area of complete dwellings (m^2)		13.46	

[b] Based on assessable area (679.91 m^2) and built floor area (200.37 m^2).

[c] Based on assessable built area (395.23 m^2) and built floor area (200.37 m^2).

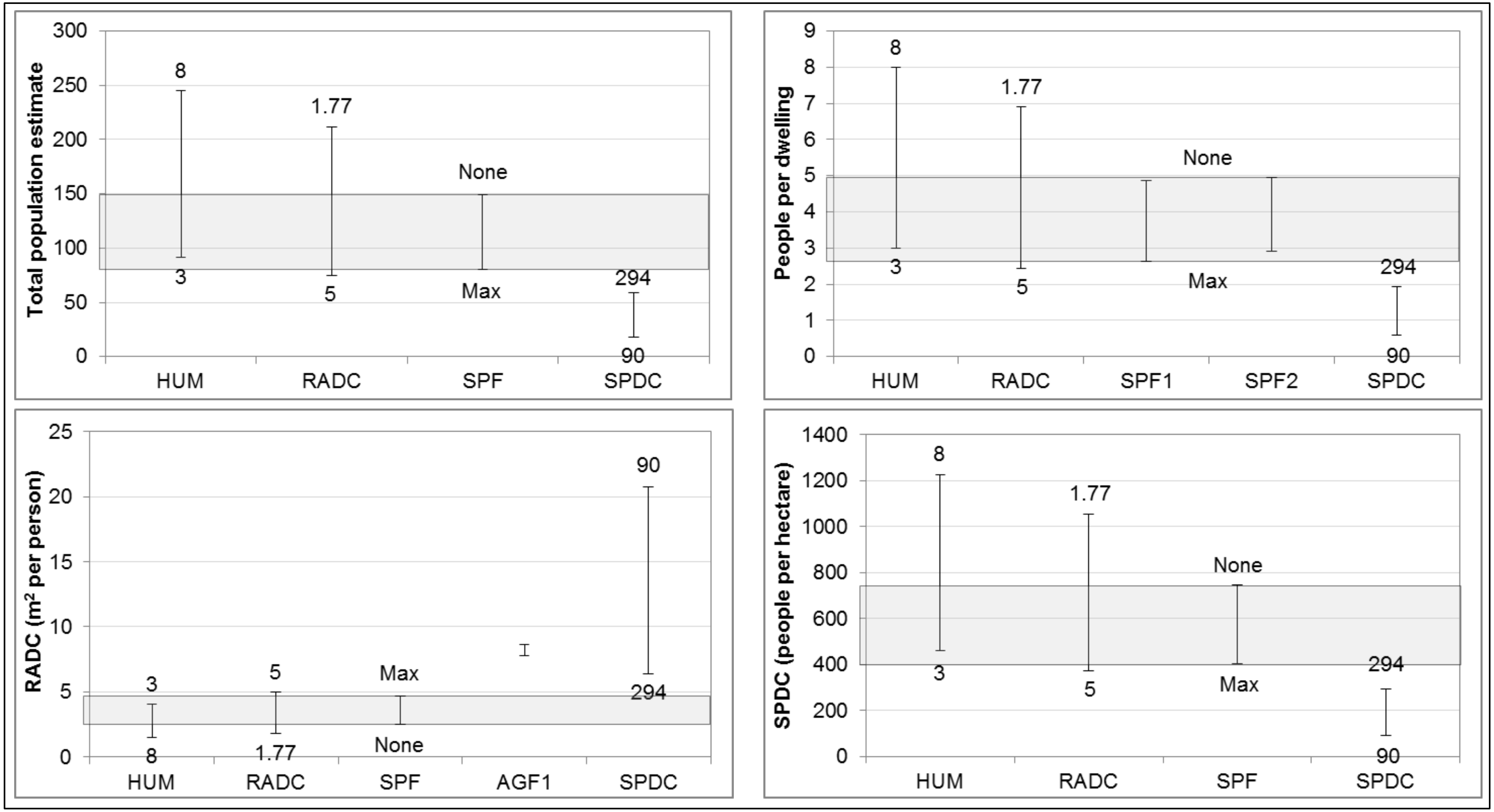


Figure 7.14. Summary of estimates for Shkārat Msaied Phase II.

7.1.6 Ghwair I

Site description

Ghwair I is a MPPNB village in southern Jordan. Excavations revealed three major architectural phases (Phases I-III) with a series of subphases (Simmons and Najjar 2006, p.80). Phase I structures consisted of very large rooms, which were generally subdivided during Phase II. Phase III comprises many multi-storey/level rectilinear houses with large and small compartments (Simmons and Najjar 2006, p.80). Investigations were conducted across multiple areas (Areas I-VI), although only the Phase III remains in Areas I and IV were excavated and interpreted in sufficient detail for inclusion in this assessment (Table 7.14; Figure 7.15).

Phase III architectural features include stone-built, rectilinear complexes on artificial terraces. These complexes include larger rooms or a large upper floor area considered to represent residential space. These residential areas are connected to smaller compartments interpreted as storage facilities. Small rooms were often constructed by sub-dividing rooms built in earlier phases. This compartmentalisation and maximisation of space suggests a high population density and a high degree of building contemporaneity (Simmons and Najjar 2006, pp.83-84).

At least two residential units were identified in Area I and four in Area IV (Table 7.15). The spatial distribution of structures in Area I is haphazard, making it difficult to determine how structures relate to each other. Conversely, Area IV structures appear to be systematically constructed according to a pre-determined plan. A communal area exists in the western portion of Area IV, containing a wide stairway leading north towards a large open plaza (Simmons and Najjar 2006, p.84). On the eastern side of Area IV, long walls that may have formed part of a water management system create long passageways providing access to the residential units.

Assessment of the remaining areas revealed a complex series of walls in Area II, probably relating to Phase III, and a large wall running parallel to the slope that may indicate water management similar to that found in Areas III and IV. It appears that Areas III and VI originally contained residential structures, although these were abandoned by Phase III and the area was utilised for waste disposal (Simmons and Najjar 2006, pp.86-87). Given the variable spatial distribution of structures and the presence of open areas, passageways and water management walls; the abandonment of some areas; and the topographical restriction of the settlement by a wadi to the south and cliffs to north, the estimated total site extent of 1.2 to 1.45

hectares (Simmons and Najjar 2003, p.407) is reduced to one hectare of potentially habitable area for calculations of population size.

Table 7.14. Description of Ghwair I Phase III* and refined variables.

Estimated site extent		12,000-14,500 m^2 (10,000 m^2 used in calculations)
Assessable area		440.75 m^2
Potential dwellings		6
Environment		On steep-moderate slope between Wadis Ghwair and Faynan and steppe hill to the south
Subsistence		Hunting, gathering, cultivation (barely, emmer, einkorn, pea; few sickles; numerous grinders), pastoralism (domesticated goats)
Architecture		Rectilinear; stone walls; single and two-storey; variable spatial layout (Area I: single-storey, free-standing; Area IV: two-storey, agglomerated); considerable subdivision and compartmentalisation; considerable remodelling
Economy		Dwelling-based production, storage, processing and consumption (numerous vessels; household autonomy); craft specialisation (tool manufacture; symbolic items); local regional centre; trade/exchange networks (clay token/seal)
Ritual/community organisation		Establish ritual activity (symbolic items; clay and stone figurines); household ritual activities (niches and burials); trade (mother of pearl; clay token/seal; incised stones); social hierarchy (items of personal adornment; unique infant burial with grave goods; houses of various size, composition and association); large public staircase leading to large open plaza
Structural contemporaneity		77.78%
Refined variables:	SPF	None-moderate (maximum excluded based on high frequency of designated storage rooms)
	AGF2	Village and urban

* Simmons and Najjar 2006; Ladah 2006.

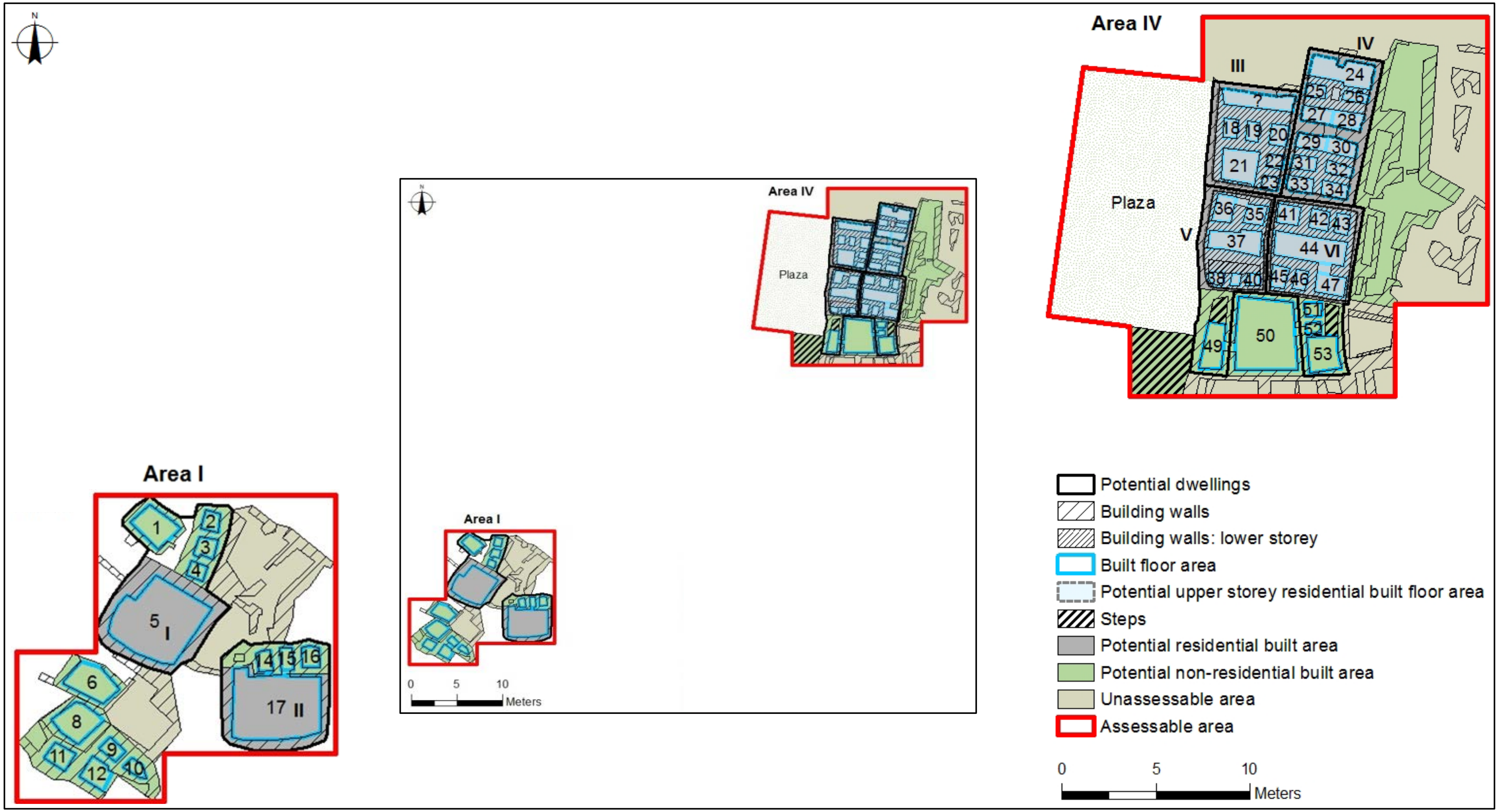


Figure 7.15. Site plan (centre) and enlarged plans of Ghwair I Phase III, Areas I and IV (transcribed from Ladah 2006, pp.97 and 117).

Table 7.15. Potential residential units identified in Ghwair I Phase III (Ladah 2006; Simmons and Najjar 2006).

Area	Unit	Room	Description	Suggested residential area
I	I	5	Large room - possibly the main living area; benches; sub-floor pits; plaster; ritual items	Room 5
		2-4	Small rooms – possible storage	
		1	Medium-sized room – possible workshop	
	II	17	Large room - possibly the main living area	Room 17
		14-16	Small rooms – possible storage	
IV	III	?	Upper storey residential area above all rooms	Upper storey area above all rooms
		21	Medium-sized basement room – possible working area	
		18-20, 22-23	Small basement rooms – possible storage	
	IV	?	Upper storey area residential above all rooms	Upper storey area above all rooms
		27-30	Medium-sized basement rooms – possible working areas	
		24-26, 31-34	Small basement rooms – possible storage	
	V	?	Upper storey area residential above Rooms 35-40	Upper storey area above Rooms 35-40
		35-36, 38-40	Small basement rooms – possible storage	
		48	Staircase leading from Room 49 (and 50) to 2nd storey of Unit 3	
		49	Lower landing of staircase; possible storage, corridor or other non-domestic purpose	
	VI	?	Upper storey residential area above Rooms 41-47	Upper storey area above Rooms 41-47
		44	Medium-sized basement room – possible working area; infant burial	
		41-43, 45-47, 51-52	Small basement rooms – possible storage	
		53	Room with ritual or ceremonial purpose	
		Staircase	Staircase leading from Room 53 (and 50) to 2nd storey of Unit 4	

Contemporaneity assessment

Simmons and Najjar (2006, p.80) assessed 22 radiocarbon determinations to refine the absolute chronology. The dates suggested an occupation span of 1,300 years. However, they identified several divergent dates, including two that were considerably earlier (ISGS 4366 and DRI 3253). These dates were removed from their assessment and an occupation span of around 500 years was suggested. Simmons and Najjar (2006, p.80) were unable to determine phase length. Following further removal of a potentially erroneous determination (ISGS 4364-bis), Benz (2013) suggested that several dates questionably attributed to Phase II (labelled Phase II?) may belong to Phase III. Prior to chronological modelling in this investigation, the two early dates (ISGS 4366 and DRI 3253) and potentially erroneous date (ISGS 4364-bis) were removed, and the four latest Phase II? dates were reassigned to Phase III.

A χ^2 test (df = 16, T = 62.501 (5% 26.3)) indicated that at least one date does not conform to the stratigraphic sequence. There is no evidence for occupational hiatus (Simmons and Najjar 2006, p.80). Therefore, a 'sequence' model was constructed representing three contiguous phases (Phases I-III with no intermittent abandonment). The model highlighted two dates with poor agreement (ISGS 4330: A = 35.5; Beta140757: A = 51.9) (Table 7.16; Figure 7.16). Removal of these dates from a subsequent run of the model revealed a further potentially divergent date (DRI 3252: A = 56.4). However, due to the limited contextual information, the proximity of the agreement value to the agreement threshold (A ≥ 60) and the high overall agreement values of the model (Amodel=163.9; Aoverall=166.4), this date was retained.

The final model indicated a Phase I start date of *8,240 to 7,610 cal BC* and a Phase III end date of *7,610 to 7,540 cal BC*, spanning up to 670 years. Modelled transition dates between Phases I and II (7*,920-7,600 cal BC*) and Phases II and III (*7,690-7,580 cal BC*) indicated spans of up to 210 years for Phase I; up to 230 years for Phase II; and up to 90 years for Phase III.

The span estimate for Phase III (the phase assessed in this investigation) appears suitable considering the architectural features and evidence for significant remodelling, including blocked wall openings, subdivisions, re-plastering and addition of supporting walls (Simmons and Najjar 2006, p.80). Archaeological, ethnographic and experimental research of comparable structures indicates potential use-life of 50 to 100 years (see Table 5.7). Structural composition is similar to buildings found at Beidha Subphase C2, which were estimated as spanning around 70 years. The Phase III span estimate (90 years) and an average building use-life estimate of 70 years produce a contemporaneity value of 77.78% for Ghwair I Phase III.

Previous population estimate

The population of Ghwair I has previously been estimated at 418 people based on van Beek's (1982) minimum population density coefficient of 286 people per hectare and an estimated site extent of 1.45 hectares (Ladah 2006).

Table 7.16. Modelled boundary dates and span estimates for Ghwair I. Highlighted dates removed from 2nd run.

					1st run			2nd run		
Phase	**Area**	**Lab reference**	**Radiocarbon date (BP)**	**Radiocarbon date range (cal BC) (95%)**	**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=69.6* *Aoverall=81.8*		**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=163.9* *Aoverall=166.4*	
						A	*C*		*A*	*C*
Start Phase I					*8280-...*		*98.3*	*8240-7610*		*97*
I	I	Hd 17219-17541	8812 ± 61	8220-7680	8180-7620	107.6	98	8160-7610	102.1	99.4
I	II	ISGS 4364	8690 ± 70	7960-7580	7980-7610	62.4	98.6	7950-7620	83.1	99.7
Span Phase I					**0-180**		**99.7**	**0-210**		**99.9**
Transition Phase I/II					*7950-7610*		*98.8*	*7920-7600*		*99.7*
II	I	DRI 3252	8880 ± 117	8290-7660	7930-7610	75.8	98.9	7880-7600	56.4	99.8
II	I	DRI 3254	8659 ± 178	8256-7360	7900-7610	124.2	99	7840-7600	136.3	99.8
II	I	ISGS 4330	8870 ± 70	8250-7750	7870-7600	35.5	99			
II?	III	DRI 3255	8755 ± 111	8210-7590	7840-7600	119.3	99.1	7800-7600	112.2	99.9
II	II	DRI 3256	8754 ± 52	8170-7600	7800-7600	97.6	99.2	7760-7590	74	99.9
II?	IV	ISGS 4333	8620 ± 70	7940-7520	7760-7590	104.9	99.4	7720-7590	129.2	99.9
Span Phase II					**0-260**		**99.3**	**0-230**		**99.7**
Transition Phase II/III					*7750-7580*		*99.4*	*7690-7580*		*99.7*
II/III?	IV	ISGS 4365	8530 ± 100	7830-7330	7720-7580	77	99.5	*7670-7580*	106.2	99.6
II/III?	II	ISGS 4325	8590 ± 70	7790-7510	7700-7580	124.2	99.6	7660-7580	160.8	99.7
II/III?	IV	Hd17221-17359	8528 ± 89	7760-7350	7680-7580	79	99.6	7650-7580	104	99.7
III	I	Beta140758	8620 ± 50	7750-7560	7660-7570	142.2	99.8	7640-7580	157.7	99.8
III	I	Beta140759	8610 ± 50	7750-7550	7640-7570	155.6	99.9	7620-7570	172.9	99.8
III?	II	ISGS 4332	8570 ± 70	7750-7490	7630-7560	170.2	99.9	7620-7570	180.1	99.8
III	I	Hd17220-17550	8627 ± 46	7740-7570	7610-7550	81.4	99.9	7610-7570	108.6	99.8
II/III?	IV	ISGS 4331	8510 ± 70	7680-7370	7600-7520	132.9	99.8	7610-7550	108.5	99.7
III	I	Beta140757	8390 ± 50	7570-7340	7600-7480	51.9	99.5			
Span Phase III					**0-200**		**99.3**	**0-90**		**99.9**
End Phase III					*7600-7450*		*99.2*	*7610-7540*		*99.5*
Span Phases I-III					**...-770**		**99.2**	**20-670**		**98**

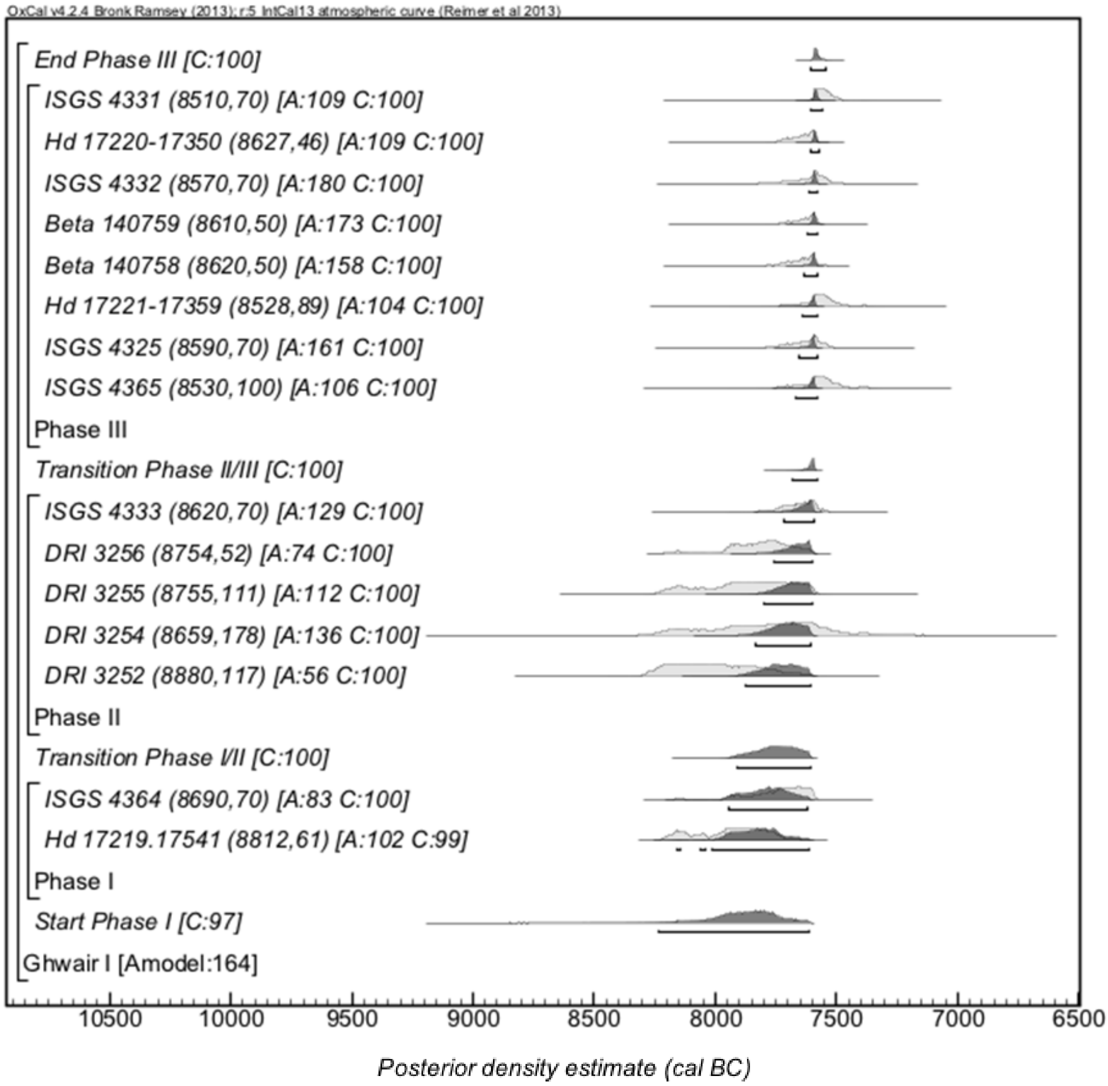


Figure 7.16. Modelled posterior density estimates for Ghwair I (2nd run: divergent dates removed).

Population estimates and group size thresholds

The SPF based on limited (none to moderate) residential storage provisions indicates a total (adult) population of around 400 to 610 people, around 3.8 to 5.8 people per dwelling, around 2.6 m^2 to four m^2 residential floor area per person and around 300 to 460 people per hectare (Table 7.17; Figure 7.17). The pre-existing population estimate (P = 418) falls at the lower end of the range derived in this investigation. The population estimate exceeds the minimum hypothesised group size threshold relating to the adoption of a fully sedentary, agro-pastoralist society (P ≥ 100). Evidence indicates that inhabitants of Ghwair I cultivated a wide range of domesticated and wild plants, including barely, emmer, einkorn, pea and medicinal plants, and engaged in pastoral practices relating to domesticated goats (Simmons and Najjar 2006, p.91).

The population estimate also exceeds the hypothesised threshold for the introduction of mechanisms to reduce scalar stress and promote social cohesion (P ≥ 150). Such mechanisms are potentially evidenced by the possible sectoring of the community into neighbourhoods and household economic units, the more formalised ritual practices, and the more structured open area for communal activities (Simmons and Najjar 2006).

The estimate also exceeds thresholds proposed for the development from a predominantly egalitarian to more hierarchical community ($P \geq 350$) and the rise of authoritative individuals ($P \geq 500$). These developments are potentially evidenced at Ghwair I by household based specialist activities and workshops potentially reflecting economically independent dwelling units; variable structural layouts possibly reflecting different dwelling unit sizes and/or different compositions and functions; and variable grave goods possibly indicating different degrees of wealth and status (Simmons and Najjar 2006).

Table 7.17. Summary of estimates for Ghwair I Phase III.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		105.88	*1603.29*	*1.325*
HUM	317.65-847.07	3-8	1.89-5.05	239.74-639.29
RADC	320.66-905.81	3.03-8.55	1.77-5	242.01-683.63
SPF1	398.92-612.25	3.77-5.78	2.62-4.02	301.07-462.08
SPF2[a]	-	3.78-5.6	-	-
AGF1[a]	-	-	4.19-4.49	-
SPDC	119.25-389.55	1.13-3.68	4.12-13.44	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (612.25)	*Moderate (398.92)*	*Maximum (324.31)*
Naroll's (1962) AGF1		17.43	25.00	29.76
Wiessner's (1974) AGF2	Open settlements	0.04	0.08	0.13
	Village settlements	21.64	33.21	40.86
	Urban settlements	183.73	244.46	280.65

Additional demographic data			
			Contemporaneous (77.78%)
Proportion (%) of site comprising:	Built area	48.23	37.51
	Residential built area	24.70	19.21
	Built floor area	29.21	22.72
	Residential floor area	15.56	12.10
Proportion (%) of assessable built area comprising:	Residential built area	51.22	
	Built floor area [b]	60.56	
	Residential floor area	32.25	
Proportion (%) of built floor area comprising residential floor area		53.26	
Mean residential floor area of complete dwellings (m^2)		15.14	

[b] Based on assessable built area (281.67 m^2) and built floor area (170.57 m^2).

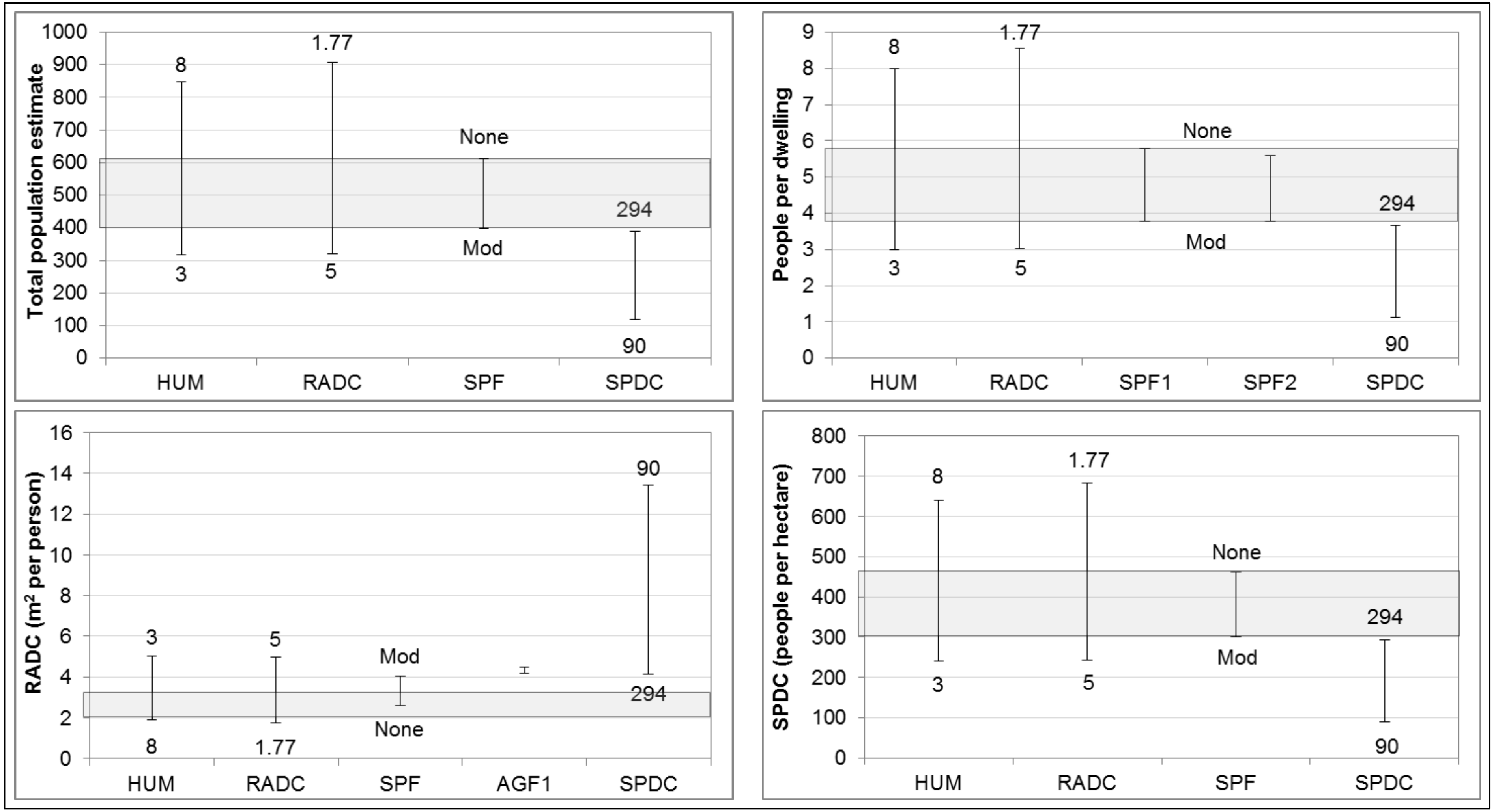


Figure 7.17. Summary of estimates for Ghwair I Phase III.

7.1.7 Wadi Hamarash I

Site description

Wadi Hamarash I is a MPPNB village in west-central Jordan (Table 7.18; Figures 7.18-7.19). Excavation across five areas (1-5) exposed numerous interconnecting, rectilinear structures. Considerably high, thick stone-walls indicate that some structures were two-storey. Clusters of structures often formed units that included a combination of single and multi-storey areas. Various elements of the architecture and structural layout resemble that of Beidha Subphase C2 (Byrd 2005a), LPPNB el-Hemmeh (White 2013), Ghwair I (Simmons and Najjar 2006) and Basta (Nissen 2006).

Identification of dwellings and residential area is partly based on interpretations by Sampson (2013a), though predominantly on analysis of the archaeological evidence for domestic activities and the structural layout of dwellings at comparable sites.

Area 1 is suggested to contain five residential units (Table 7.19). Sampson (2013a, p.8) identifies two “houses” (Units I and II) and a potential “special residence” (Unit III). The remaining units (IV and V) are assigned as residential units based on domestic archaeological features. Structures identified as non-residential include Locus 28, which contained an upright standing stone at its centre; and Locus 22, which contained unique features and remains, including burnt soil, animal bones and two possible benches.

Area 2 is suggested to contain four residential units. Sampson (2013a) identifies two “units” (I and II). These, and two further units (III and IV), are assigned as residential in this investigation based on the presence of domestic artefacts and architectural features. It is probable that further residential units occur within this area. Structures identified as non-residential include a “unit” (Loci 16-19 and 25) adjacent to the large communal building in Area 4, containing colour-coated plaster floors and walls, built-in benches, a set of gazelle antlers and unique stone objects (Sampson 2013a, p.33); Locus 13, which comprised fine masonry and contained a hearth, a large quern and many blades and arrowheads (Sampson 2013a, pp.12-13); a corridor (Locus 14); an open area with a unique feature comprising a large flint nodule placed on a large slab (Locus 21); and a series of medium-sized workshop areas containing numerous lithics and animal bones (Loci 2, 8, 11-13 and 15), querns (Locus 11 and 15), ground stone tools and stone vessels (Loci 11, 13 and 15). It is probable that a number of these structures formed a unit with Locus 1.

Area 3 is suggested to contain three residential units. Sampson (2013a) identifies “a large property” (Unit I), which contains at least two large rooms connected to a series of small rooms or storage areas; and a “building” (Unit II) which comprises at least two larger rooms and a small narrow area. These, in addition to Unit III are assigned here as residential based on domestic artefacts and architectural form.

Area 4 contained a large, rectangular, structure with fine masonry, a rectangular hearth, drainage channels, niches and a circular pit surrounded with stones containing an incised, spherical flint nodule. This structure was associated with an external rectangular niche and ortholith, potentially indicating a ritual function. A courtyard area measuring at least 15 m by 20 m extended towards the northwest (Sampson 2013a, pp.22-23).

Area 5 is suggested to contain four residential units. Sampson (2013a) identifies a “channel house” (Unit I) based on the presence of sub-floor stone-built channels usually interpreted as water management (Goring-Morris and Belfer-Cohen 2010) or ventilation shafts (Kuijt and Goring-Morris 2002, p.409). The remaining units (II-IV) have been assigned based on architectural layout and domestic artefacts. High frequencies of ground stone tools and stone vessels within structures in the southern, unassessed portion of Area 5 may indicate food processing and consumption practices from further residential contexts.

A total of 16 potential dwellings were identified. Although speculative, the suggestions made in this assessment allow some progress towards understanding the demographic parameters at this site.

Table 7.18. Description of Wadi Hamarash I* and refined variables.

Estimated site extent		5,000 m^2
Assessable area		1,249.49 m^2
Potential dwellings		16
Environment		On a constricted plateau above intercept of the Wadis al-Hasa and Hamarash-Suweif with steep mountains to the north; enclosed by stone wall
Subsistence		Hunting, gathering, cultivation (einkorn, emmer, barley; 900 ground stone tools), pastoralism (potentially domesticated goats and sheep)
Architecture		Rectilinear; stone walls; diverse forms; two-storey; considerable subdivision and compartmentalisation; considerable remodelling
Economy		Dwelling-based production, storage, processing and consumption (grinding stones; stone vessels; household autonomy); craft specialisation (small scale processing of stone, shell and bone objects and jewellery); specific specialist activity areas (perforated objects in different areas); possibly part of a "hydraulic society" situated along the wadi
Ritual/community organisation		Established ritual activity (Area 4: large, central communal building and courtyard with symbolic items – ortholith; flint nodules, stone objects, decorative objects, items of personal adornment, symbolic incisions; possible human figurine); social differentiation/social status (different architectural forms and displays of wealth); possible sectoring of site into neighbourhoods
Structural contemporaneity		78%
Refined variables	SPF	None-moderate (maximum excluded based on high frequency of designated storage rooms)
	AGF2	Village and urban

* Donta 2013; Gkotsinas and Karathanou 2013; Sampson 2013a; 2013b; Tampakopoulou 2013.

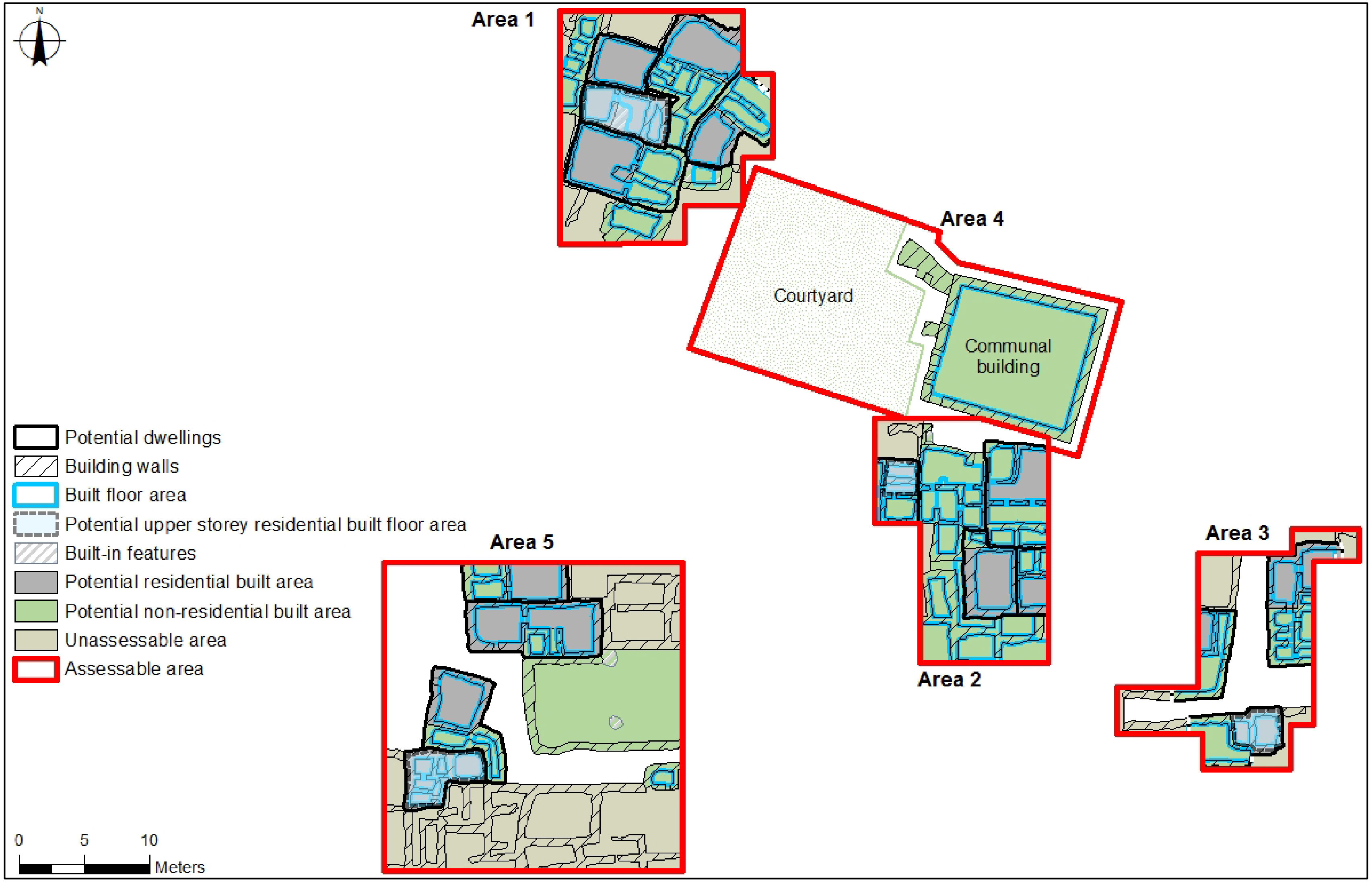


Figure 7.18. Site plan of Wadi Hamarash I (transcribed from Sampson 2013a, pp.8, 12, 15, 18, 23 and 24).

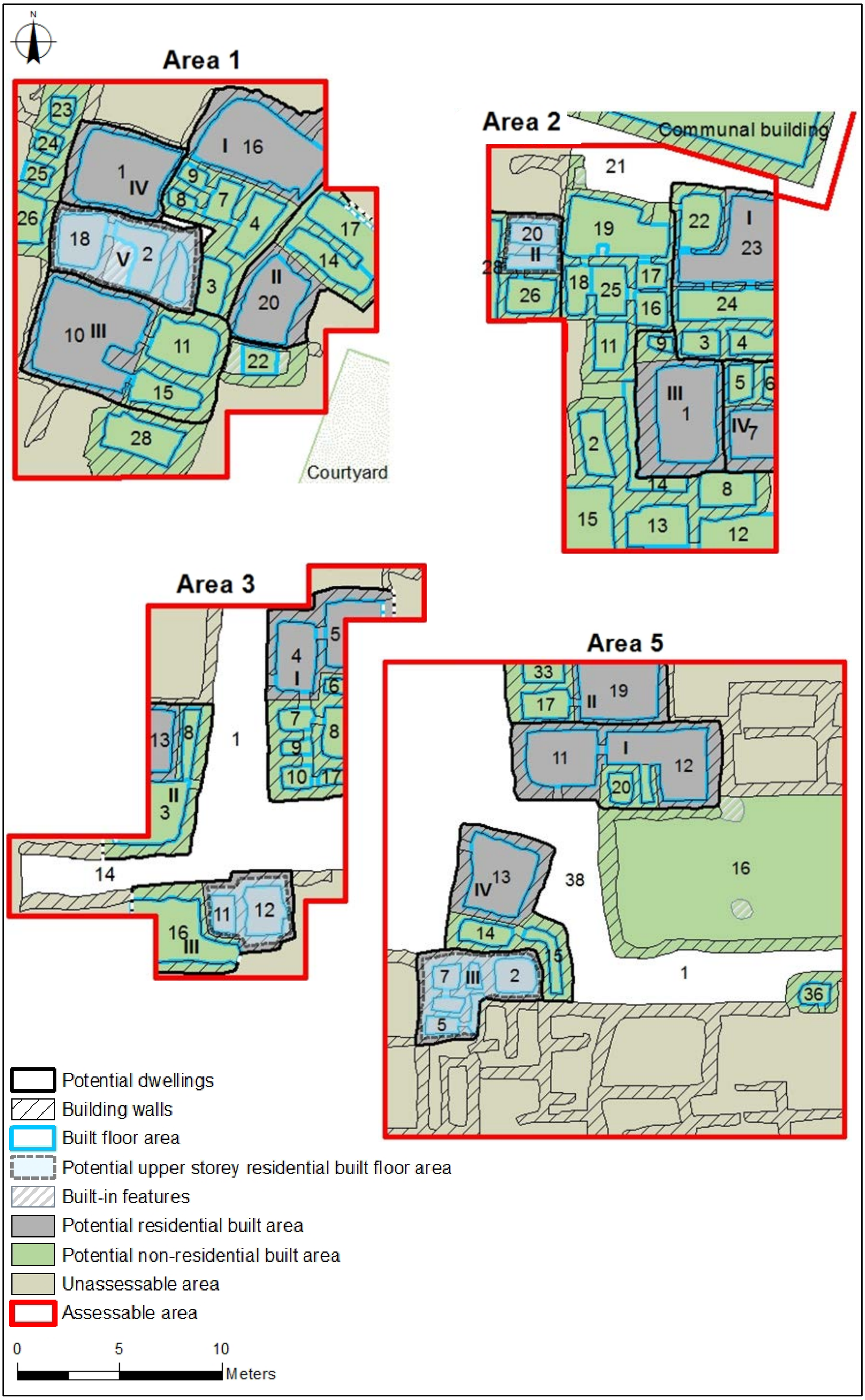


Figure 7.19. Enlarged plans of Wadi Hamarash I, Areas 1, 2, 3 and 5 (transcribed from Sampson 2013a, pp.8, 12, 15, 18, 23 and 24).

Table 7.19. Potential residential units identified in Wadi Hamarash I.

Area	Unit	Locus	Description	Suggested residential area
1	I	16	Numerous ground stone tools; interpreted as the main room of the residence (Sampson 2013a, p.10); two storey	Locus 16 (or an upper storey of comparable size)
		7, 8, 9	Three small storage features connected by narrow passages - ground floor storage rooms	
		3, 4	Not described; possible storage or work areas	
	II	14	Possible corridor or storage area	Locus 20 (or an upper storey of comparable size)
		17	Possible storage area	
		20	Large room - possibly the main living area; the thickness of the walls indicate possible two storey structure	
	III	10	Large room of a potentially 'special' residence (Sampson 2013a, p.11); two-storey	Locus 10 (or an upper storey of comparable size)
		11, 15	Two smaller ground floor loci connected to Locus 10; probable storage areas	
	IV	1	Large room - possibly the main living area; buttressing suggests two-storey structure (Sampson 2013a, p.7); numerous episodes of reconstruction and remodelling; much later partitioning walls; many grinding implements; two stone mortars; two floors preserved	Locus 1 (or an upper storey of comparable size)
	V	2	Thick walls and a hard surface (probably a floor) reached at a depth of 2.1 m indicate that the structure may have been two-storey (Sampson 2013a, p.9); contained two semi-circular storage areas on the western side; many ground stone tools; many querns, a millstone, a flint borer and two perforated rounded stones; querns used in wall construction; human and unidentified skeletal fragments; doorway to Locus 18	An upper storey area covering Loci 2 and 18
		18	Accessed via the roof or an upper storey; high walls indicate an upper storey; many querns; querns used in wall construction; necklace of flat, drilled stones; flint blades and fragments; many drill borers possibly for stone working; skeletal fragments, perforated shell, numerous stone tools, flint cores and a perforated rounded sandstone; limestone bowls and other stone vessels; a possible game board; two benches; may also have been utilised for the manufacture of decorative items as indicated by the high frequencies of borers and perforated stones	
2	I	3, 4	Small independent loci; many ground stone tools and lithic artefacts	Locus 23
		22	Smaller room at entrance; many ground stone tools and lithic artefacts	
		23	Large room - possibly the main living area; many ground stone tools and lithic artefacts; plastered floor	
		24	Many ground stone tools and lithic artefacts; elongated with 2 doors leading to main room	
	II	20	Buttresses and very high walls (> 2.2 m) indicate two storey; red and yellow painted ellipsoid stone object with incised decoration; big stone basins and smaller vases; two grinders; stone vessels and fragment; flint blades; animal bones; phallic shaped stone	Locus 20 (or an upper storey of comparable size)
		26	Ground floor unit; small entrance via Locus 20; many ground stone tools	
		28	Ground floor unit; small entrance via Locus 20 (incompletely excavated)	

Area	Unit	Locus	Description	Suggested residential area
2	III	1	Large, two storey structure; thick stone walls made of large stones; burnt soil and remains, arrowheads, large stone vessel fragments, quern fragments; animal bones; green stone bead, two stone balls; fine masonry; ground floor remains infer ritual significance	Locus 1 (or an upper storey of comparable size)
		9	Very small locus; many ground stone tools and lithic artefacts	
	IV	7	Larger area connected to two storage rooms	Locus 7
		5, 6	Small storage rooms	
3	I	4, 5	Larger rooms; possible ground floor residential area; connected to a series of smaller rooms	Loci 4 and 5
		7-10, 17	Small storage areas; narrow doorways; ground floor; stone vessel fragments in Locus 7	
	II	3	Larger area; possible courtyard	Locus 13 (or an upper storey of comparable size)
		8	Very narrow space; possible storage area	
		13	Possible two-storey room	
	III	12	Two-storey indicated by considerably high walls; stone vessel fragment	An upper storey area covering Loci 11 and 12
		11	Smaller storage room	
		16	Ground floor; two stone vessel fragments	
5	I	11	Stone slab pavement covered with lime plaster; plaster probably on walls; two large querns; sub floor channels under pavement; stone vessel fragment	Loci 11 and 12
		12	Large room; stone vessel fragments	
		20	Storage space	
	II	17	Storage room	Locus 19
		19	Stone vessel fragments	
		33	Storage room	
	III	2	Traces of burning; several ground stone tools; sandstone slab with two rows of cup-marks (palette or game board); semi-spherical sandstone	An upper storey area covering all loci
		5	Caprid bones; stone sphere with circular groove; bone ring; perforated oblong shell piece; broken shell pendant; grinder, mortars, bones; passage leads to Locus 7; stone vessel fragment	
		7	Passage leads to Locus 5; burnings; lithics, animals bones, shell pendants; partitioned; many cereal seeds; few flint blades; a grinder; few animals bones; large group of burned stones, large quern and grinder in lower levels; entrance to this unit must have been from a roof or upper storey; evidence for buttressing indicates upper storey	
	IV	13	Large room; two perforated shells	Locus 13
		14, 15	Narrow storage rooms	

Contemporaneity assessment

Wadi Hamarash I has been radiocarbon dated to between 8,710 ± 50 BP (7,940-7,590 cal BC) and 8,425 ± 45 BP (7,590-7,360 cal BC). Unfortunately, no information is available regarding context or material sourced. Sampson (2013a, p.27) suggests that there is little temporal variation between earlier and later strata, though he provides no further information regarding the stratigraphic sequence.

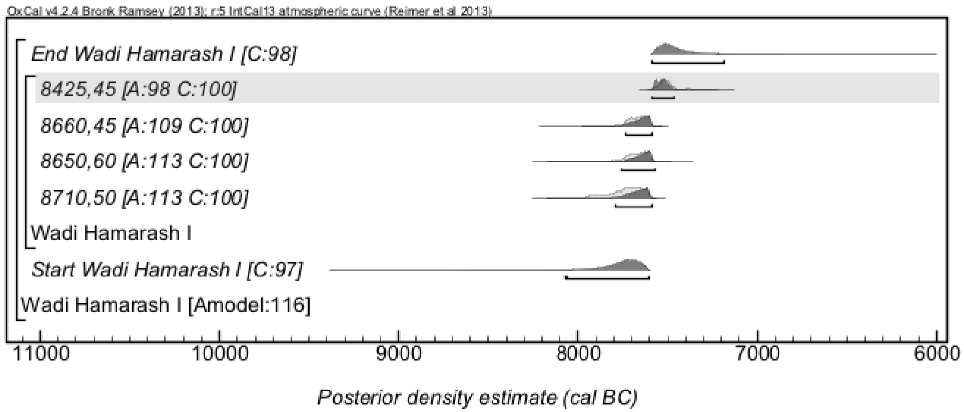
A χ^2 test (df = 3, T = 22.178 (5% 7.8)) indicated that at least one date does not conform to the stratigraphic sequence. Observation of the calibrated date ranges indicates that the latest date may not belong to the same strata as the three earlier dates. Removal of this date from a subsequent χ^2 test (df = 2, T = 0.8 (5% 6.0)) indicated that the three earlier dates form one coherent stratigraphic group.

A single 'phase' model was constructed and applied to the full and reduced dataset. The final model indicates a start date of *8,100 to 7,600 cal BC*, an end date of *7,750 to 7,260 cal BC*, and a span of up to 170 years (Table 7.20; Figure 7.20).

Architectural evidence indicates a significant expenditure of effort on construction of the thick-walled and often multi-storey structures, particularly those containing fine masonry. There is considerable evidence for remodelling and reconstruction throughout the site, suggesting that the majority of structures may have been utilised for an extended period, and probably contemporaneously. Archaeological, ethnographic and experimental research of masonry structures with considerable maintenance indicate a potential use-life of between 75 and 100 years (see Table 5.7). If the maximum building use-life (100 years) is used in conjunction with the modelled occupation/phase span estimate (170 years), this produces a contemporaneity value of 58.82%. There appears to be one main phase of construction and limited evidence for superpositioning or abandonment of structures indicating a high degree of contemporaneity. Values derived for comparable sites in this analysis range from around 60% (Basta) to around 78% (Beidha Subphase C2 and Ghwair I). The higher value (78%) is considered more suitable for Wadi Hamarash I given the evidence for high structural contemporaneity and is, thus, used in this investigation.

Table 7.20. Modelled boundary dates and span estimates for Wadi Hamarash I. Date highlighted in grey removed from 2nd run.

Context	Radiocarbon date (BP)	Radiocarbon date range (cal BC) (95%)	1st run: Posterior density estimate range (cal BC) (95.4%)	1st run: Indices *Amodel=116.4* *Aoverall=116.3*		2nd run: Posterior density estimate range (cal BC) (95.4%)	2nd run: Indices *Amodel=120.6* *Aoverall=119.3*	
				A	*C*		*A*	*C*
Start Wadi Hamarash I			*8080-7600*		*97.2*		*8100-7600*	*97.9*
R_Date(8710, 50)	8710 ± 50	7940-7590	7800-7590	112.6	99.8	7800-7590	116.9	99.7
R_Date(8650, 60)	8650 ± 60	7940-7570	7760-7570	113.1	99.8	7760-7580	111.1	99.8
R_Date(8660, 45)	8660 ± 45	7790-7580	7740-7580	108.7	99.9	7750-7590	104.6	99.8
R_Date(8425, 45)	8425 ± 45	7590-7360	7590-7460	97.7	99.8			
End Wadi Hamarash I			*7590-7180*		*98*		*7750-7260*	99.4
Span Wadi Hamarash I			**30-320**		**99.7**	**0-170**		***98.5***



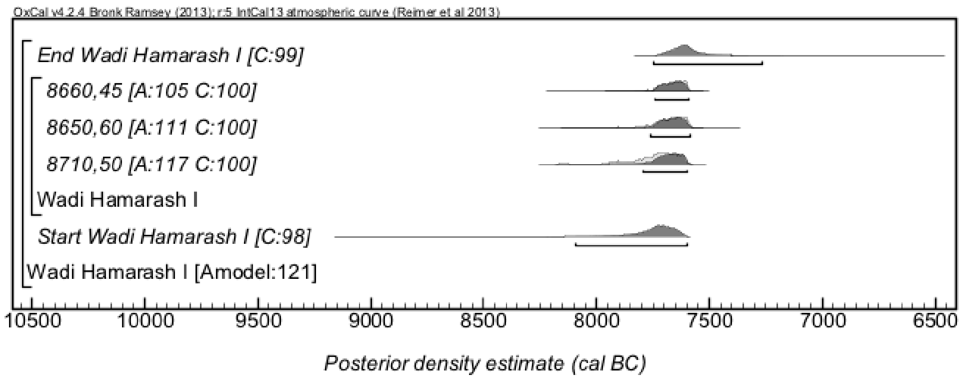


Figure 7.20. Modelled posterior density estimates for Wadi Hamarash I. 1st run (left) and 2nd run (right) following removal of highlighted date.

Population estimates and group size thresholds

The SPF based on limited residential storage provisions indicates a total (adult) population of around 145 to 220 people, around 2.9 to 4.5 people per dwelling, around 2.6 m^2 to 3.9 m^2 residential floor area per person and around 290 to 450 people per hectare (Table 7.21; Figure 7.21). The population estimate exceeds the minimum group size threshold relating to the adoption of a fully sedentary, agro-pastoralist society (P ≥ 100). Evidence suggests intensive cultivation of a wide range of plants including einkorn, emmer and barley (although it is currently unclear whether these were domesticated), and pastoral practices relating to potentially domesticated goats and sheep (Gkotsinas and Karathanou 2013).

The estimates also fit with thresholds relating to the introduction of mechanisms for reducing scalar stress and promoting social cohesion (P ≥ 150). This is potentially evidenced by the sectoring of the community into household economic units and possible neighbourhoods, as indicated by streets dissecting the village and variable structural layout within each area. This may also be evidenced by the more elaborate ritual structures and features (i.e. ortholith; spherical nodule); and the potentially centralised organisation of the settlement and communal activities, as indicated by the unique, large, centrally located, non-domestic building and associated courtyard, and highly organised spatial layout of streets and communal areas throughout (Sampson 2013a).

Diverse structural forms, variable structural layout, craft specialisation, decorative objects and items of personal adornment (Sampson 2013a; 2013b; Tampakopoulou 2013) may all suggest an increasingly hierarchical and complex society (expected to occur at P ≥ 350). The well-structured layout of the settlement and the highly formalised non-domestic space may indicate the presence of an individual or group of individuals with authoritative, decision-making powers (expected to occur at P ≥ 500). Wadi Hamarash I may have formed part of a “hydraulic society” with other settlements along the wadi, including adjacent sites Wadi Hamarash II and IV, and settlements at Khirbet Hammam and possibly el-Hemmeh (Sampson 2013a, p.31). Exchange of ideas, products and people through this network may have produced more advanced developments than expected for this comparatively low population size. Of course, given the tentative and conservative identification of residential area in this investigation, it is possible that the population has been underestimated.

Table 7.21. Summary of estimates for Wadi Hamarash I.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 49.94	*Based on total contemporaneous residential floor area (m^2): 566.58*	*Based on total site extent (ha): 0.5*
HUM	149.82-399.53	3-8	1.42-3.78	299.64-799.05
RADC	113.32-320.10	2.27-6.41	1.77-5.00	226.63-640.2
SPF1	146.62-222.52	2.94-4.46	2.55-3.86	293.23-445.05
SPF2[a]	-	3.06-4.44	-	-
AGF1[a]	-	-	3.67-3.92	-
SPDC	45-147	0.9-2.94	3.85-12.59	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage:		
		None (222.52)	*Moderate (146.62)*	*Maximum (121.15)*
Naroll's (1962) AGF1		19.30	27.43	32.21
Wiessner's (1974) AGF2	Open settlements	0.10	0.23	0.34
	Village settlements	22.47	34.10	41.27
	Urban settlements	136.14	179.79	204.18

Additional demographic data			Contemporaneous (78%)
Proportion (%) of assessable area comprising:	Built area	63.16	49.26
	Residential built area	21.98	17.15
	Built floor area [b]	36.56	28.52
	Residential floor area	14.53	11.33
Proportion (%) of assessable built area comprising:	Residential built area	34.80	
	Built floor area [c]	57.89	
	Residential floor area	23.00	
Proportion (%) of built floor area comprising residential floor area		39.73	
Mean residential floor area of complete dwellings (m^2)		12.22	

[b] Based on assessable area (1249.48 m^2) and built floor area (456.85 m^2).
[c] Based on assessable built area (789.16 m^2) and built floor area (456.85 m^2).

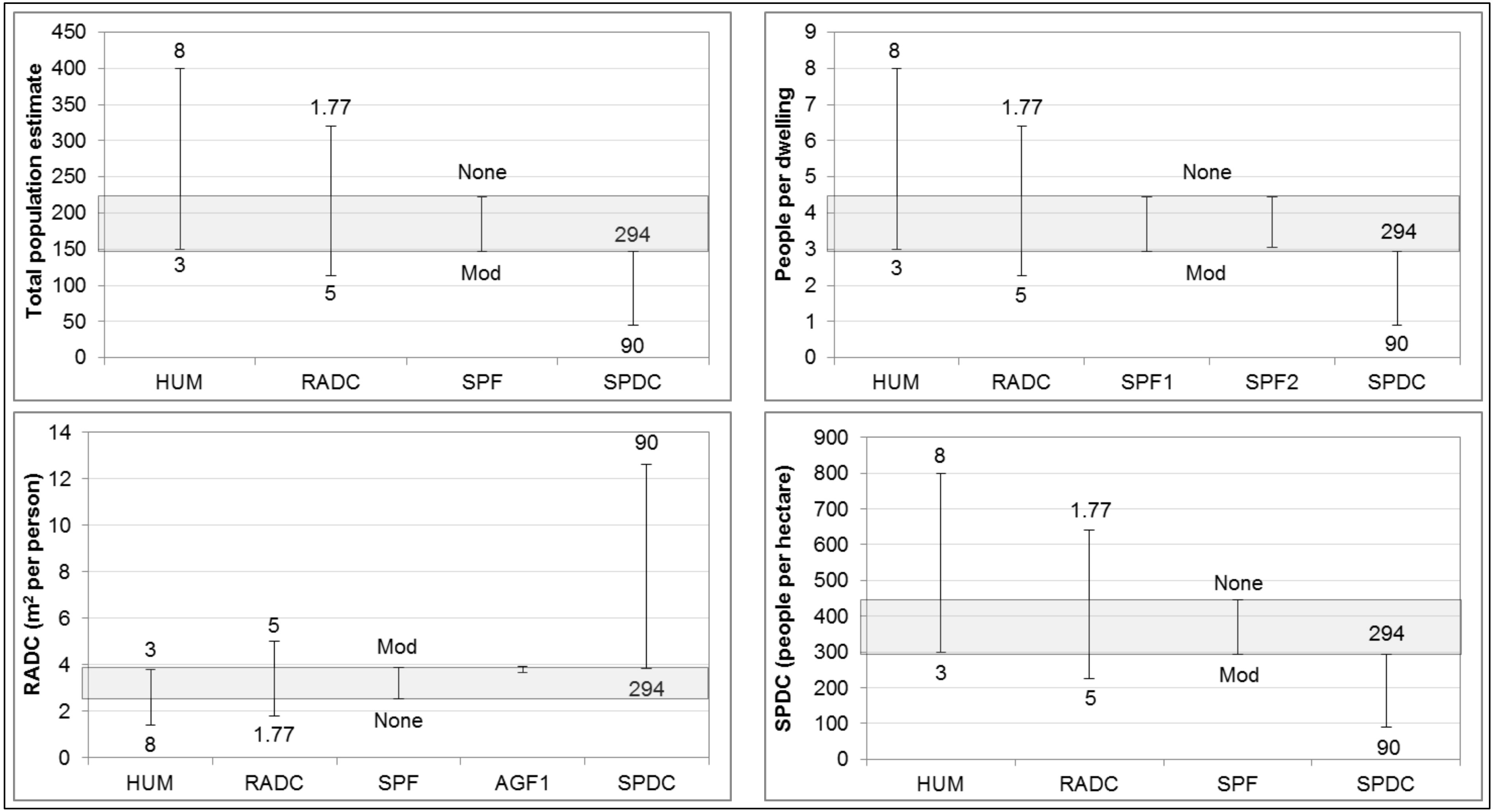


Figure 7.21. Summary of estimates for Wadi Hamarash I.

7.1.8 ’Ain Abu Nekheileh

Site description

‘Ain Abu Nekheileh is a late MPPNB village in southern Jordan (Table 7.22.; Figure 7.22). Three main phases were excavated. Phase III is the major period of settlement and is assessed in this investigation (Henry *et al.* 2002, p.15). Excavations across two blocks (I-II) revealed a series of high density, interconnected, semi-subterranean, structures of predominantly curvilinear, stone walls (Henry *et al.* 2003; Henry and Albert 2004). Surface evidence indicates similar structural remains over an area of around 1,200 m^2 (Henry *et al.* 2003, p.5). Larger structures with walls two to three courses thick (Loci 1-5, 11, 20, 22 and 25) were interpreted as stone lined pit-houses (Henry *et al.* 2002; 2003). These structures contained domestic features such as hearths, querns, ground stone implements and caches of points. Several contained discreet storage features separate from the residential floor area and were adjoined by additional storage facilities (Loci 1-3, 5, 20 and 22). Locus 20 contained a working platform and high frequencies of spherulites from sheep and goat dung, potentially indicating partial or temporary use as a pen for herding animals (Henry *et al.* 2003, p.12; Henry and Albert 2004, p.91). However, as the timing of this change of function is uncertain, Locus 20 is assessed as a dwelling in this investigation based on the concentration of domestic artefacts. A sub-rectangular building (Locus 3) contains an internal pillar of the same height as the external wall, which may indicate an upper storey (Henry *et al.* 2003, p.9).

Table 7.22. Description of ‘Ain Abu Nekheileh Phase III* and refined variables.

Estimated site extent		1,200 m^2
Assessable area		135.3 m^2
Potential dwellings		9
Environment		On hill on edge of Wadi Rum; within steep canyon near water inundated mudflat
Subsistence		Hunting, gathering, cultivation (300+ grinding stones; sickles), potential pastoralism (goats and sheep)
Architecture		Predominantly curvilinear with some transitional rectilinear forms; organised in clusters; semi-subterranean; thick stone walls; organic roofing; built in storage features; moderate subdivision and compartmentalisation; some remodelling
Economy		Dwelling-based storage, production and processing (grinding tools, querns and hearth); possible communal consumption (no stone vessels; may have been a lack of suitable stone material); potential craft specialisation (naviform core technology; preference for pink chert); trade network (ornamental shell); potential broader network with Jebel Ragref, Jebel Arqa, Jebel Salaqa and Jebel Rabigh.
Ritual/community organisation		Potential social hierarchy or symbolism (items of personal adornment - ornamental shell)
Structural contemporaneity		65%
Refined variables:	HUM	Minimum-average (maximum nuclear family size excluded due to insufficient mean residential floor area (7.98 m^2))
	AGF2	Village

* Henry *et al.* 2002; 2003; Fabiano *et al.* 2004; Henry and Albert 2004.

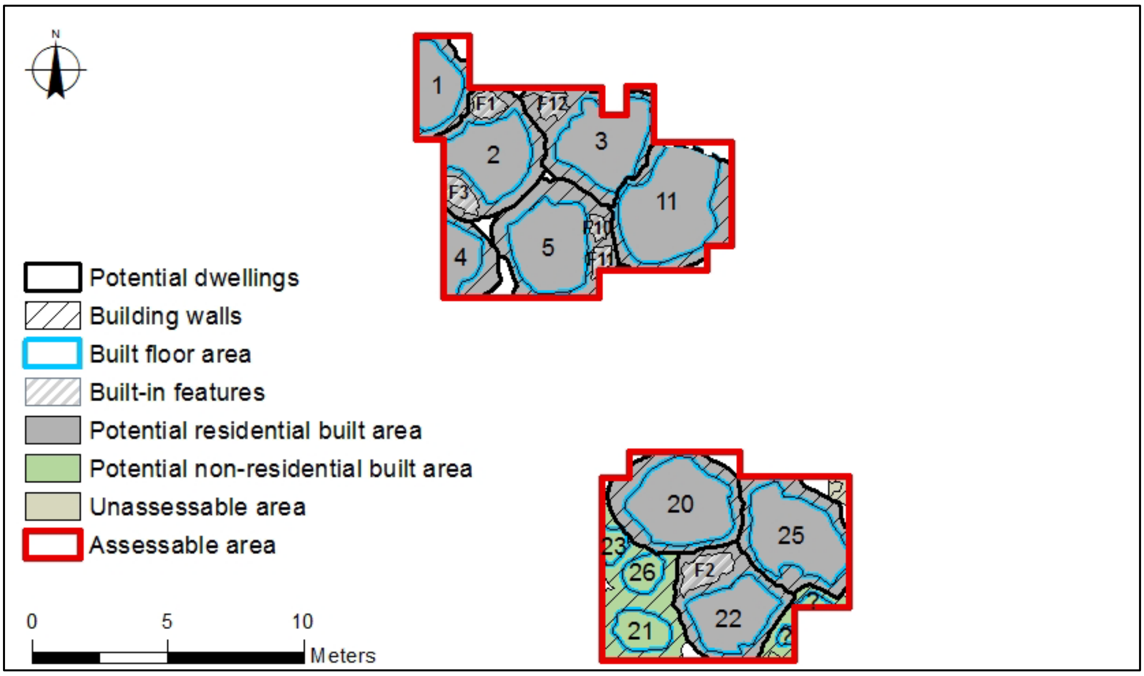


Figure 7.22. Site plan of ‘Ain Abu Nekheileh Phase III, Blocks I (north) and II (south) (transcribed from Henry *et al.* 2003, p.7).

Contemporaneity assessment

Henry and Albert (2004, p.82) suggest a total occupation span of 180 to 260 years. This included three occupational phases (I-III) and probably a short period of abandonment between Phases II and III.

Structures comprised thick, interconnected stone walls, probably with organic roofing (Henry *et al.* 2003). Re-occupation of several Phase II structures during Phase III indicates considerable use-life in some cases. Archaeological, ethnographic and experimental research of comparable structures indicates a potential use-life of between 35 and 75 years (see Table 5.7). Structures demonstrate strong similarities with those of Beidha Phases A and B, estimated at 50 to 100 years use-life (Byrd 2005a), and Shkārat Msaied (Kinzel 2013).

Sufficient radiocarbon dates exist for Bayesian chronological modelling of ‘Ain Abu Nekheileh. A χ^2 test (df = 5, T = 8.6 (5% 11.1)) indicated that all dates conform to one coherent stratigraphic group. The loci from which the radiocarbon dates are sourced (Locus 2, 5, 20, 22 and 25) were all occupied during Phase III, although Loci 20, 22 and 25 appear to have been originally constructed during Phase II (Figure 7.23). The lack of chronostratigraphic order of dates, even within the same structure (Locus 20) prevents allocation of dates to a specific phase. As such, a Bayesian chronological model was constructed representing one phase (Phases II/III combined), containing an individual building phase model for Locus 20 and a separate phase model for all other loci.

The model indicates a Phase II start date of between *7,830* and *7,530 cal BC* and a Phase III end date of between *7,590* and *7,300 cal BC* (Table 7.23; Figure 7.24). The model indicates a span of up to 290 years for Phases II and III. The modelled span for Locus 20, which was occupied during Phases II and III, was up to 190 years. Unfortunately, as the proportion of spans relating to each phase remains unclear, span estimates for Phase III could not be further refined. However, as both estimates incorporate dates from both phases, these were considered suitable for reconstructing a structural contemporaneity value of 65%.

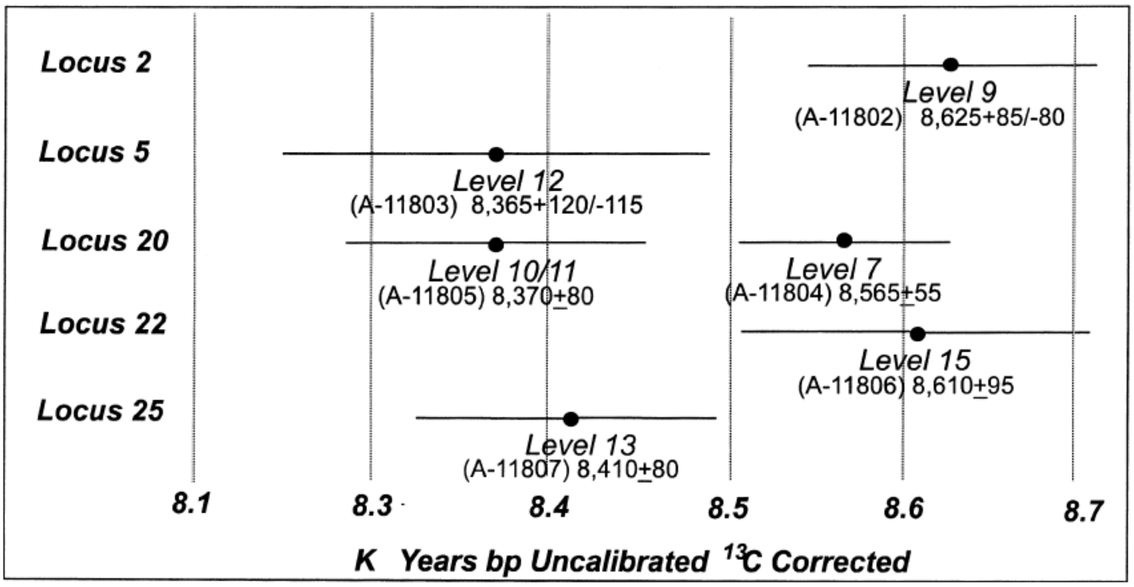


Figure 7.23. Radiocarbon dates for ‘Ain Abu Nekheileh (Henry *et al.* 2003, p.13)

Table 7.23. Modelled boundary dates and span estimates for 'Ain Abu Nekheileh.

Locus	Lab reference	Phase	Context	Radiocarbon date (BP)	Radiocarbon date range (cal BC) (95%)	Posterior density estimate range (cal BC) (95.4%)	Indices *Amodel=122.8* *Aoverall=118.7* *A*	*C*
Start Phase II						*7830-7530*		*98.2*
20	A11804	II/III	Level 7	8565 ± 55	7720-7520	7640-7520	110.6	99.8
	A11805		Level 10/11	8370 ± 80	7580-7180	7600-7400	81.7	99.5
	Span Locus 20					**0-190**		**99.3**
22	A11806	II/III	Level 15	8610 ± 95	7960-7490	7700-7500	112.2	99.7
2	A11802	III	Level 9	8625 ± 85	7940-7520	7700-7510	99.2	99.6
25	A11807	II/III	Level 13	8410 ± 80	7600-7190	7600-7420	105.9	99.7
5	A11803	III	Level 12	8465 ± 120	7790-7170	7660-7410	142.8	99.7
End Phase III						*7590-7300*		*98.6*
Span Phases II/III						**0-290**		**97.5**

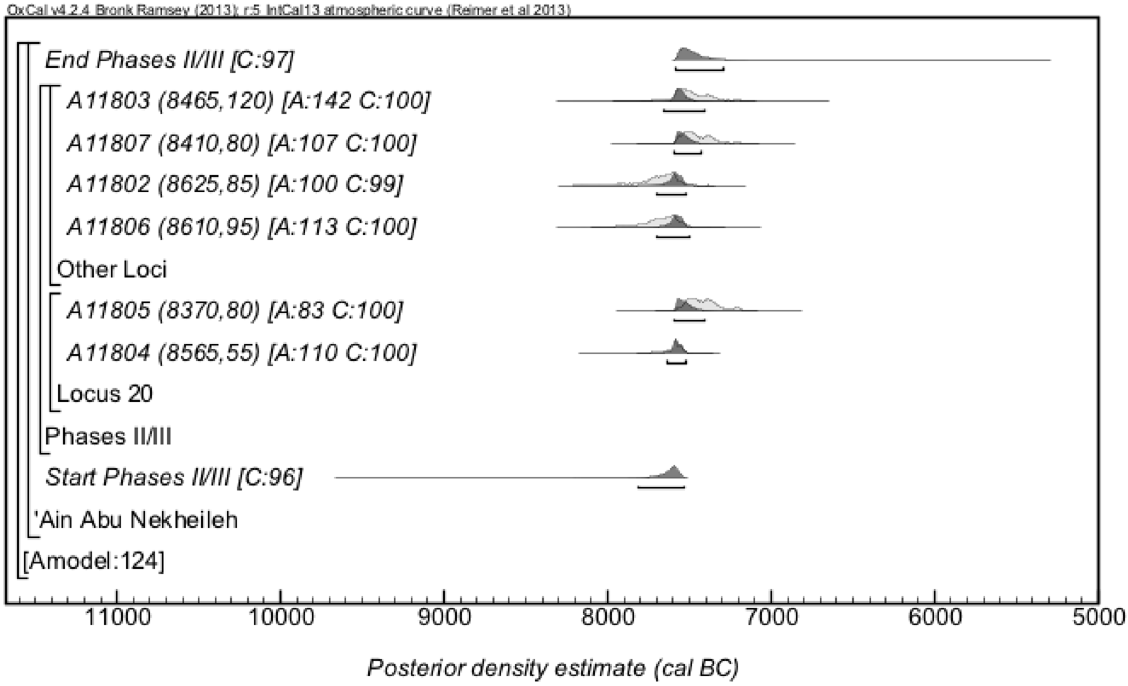


Figure 7.24. Modelled posterior density estimates for ‘Ain Abu Nekheileh.

Population estimates and group size thresholds

The SPF indicates a total (adult) population of around 85 to 150 people, around 1.7 to 2.9 people per dwelling, around 2.6 m^2 to 4.5 m^2 residential floor area per person and around 710 to 1,230 people per hectare (Table 7.24; Figure 7.25). The population estimate exceeds the hypothesised group size thresholds relating to initial sedentism (P ≥ 25) and the adoption of farming practices (P ≥ 50); and is comparable to the minimum threshold for the transition to a fully sedentary, agro-pastoralist subsistence strategy (P ≥ 100). Evidence suggests that the inhabitants of ‘Ain Abu Nekheileh cultivated cereals and engaged in pastoral practices relating to potentially domesticated goats and sheep (Albert and Henry 2004, p.83).

‘Ain Abu Nekheileh also exhibits a number of attributes that reflect the transition from a more egalitarian to more complex society, hypothesised to occur at higher population levels (P ≥ 350). This includes evidence for formalised ritual activity and economically independent household units as indicated by dwelling based storage, production and consumption activities (Henry *et al.* 2003). The village appears to have formed part of wider network with other sites in the region, including Jebel Ragref, Jebel Arqa, Jebel Salaqa and Jebel Rabigh (Fabiano *et al.* 2004). This could explain the presence of such processes despite the small population estimate.

Table 7.24. Summary of estimates for ‘Ain Abu Nekheileh Phase III.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		51.88	*385.56*	*0.12*
HUM	155.65-285.37	3-5.5	1.35-2.48	1297.12-2378.05
RADC	77.11-217.83	1.49-4.2	1.77-5	642.59-1815.23
SPF1	85.6-147.76	1.65-2.85	2.61-4.5	713.34-1231.37
SPF2[a]	-	1.88-2.77	-	-
AGF1[a]	-	-	9.02-9.84	-
SPDC	10.8-35.28	0.21-0.68	10.93-35.7	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage:		
		None (147.76)	*Moderate (99.93)*	*Maximum (85.6)*
Naroll's (1962) AGF1		9.65	13.42	15.29
Wiessner's (1974) AGF2	Open settlements	0.05	0.12	0.16
	Village settlements	8.12	12.01	14.02
	Urban settlements	42.93	55.72	61.77

Additional demographic data			
			Contemporaneous (65%)
Proportion (%) of assessable area comprising:	Built area	95.46	62.05
	Residential built area	83.95	54.57
	Built floor area[b]	53.97	35.08
	Residential floor area	49.43	32.13
Proportion (%) of assessable built area comprising:	Residential built area	87.94	
	Built floor area[c]	56.53	
	Residential floor area	51.78	
Proportion (%) of built floor area comprising residential floor area		91.59	
Mean residential floor area of complete dwellings (m^2)		7.98	

[b] Based on assessable area (135.3 m^2) and built floor area (73.02 m^2).
[c] Based on assessable built area (129.16 m^2) and built floor area (73.02 m^2).

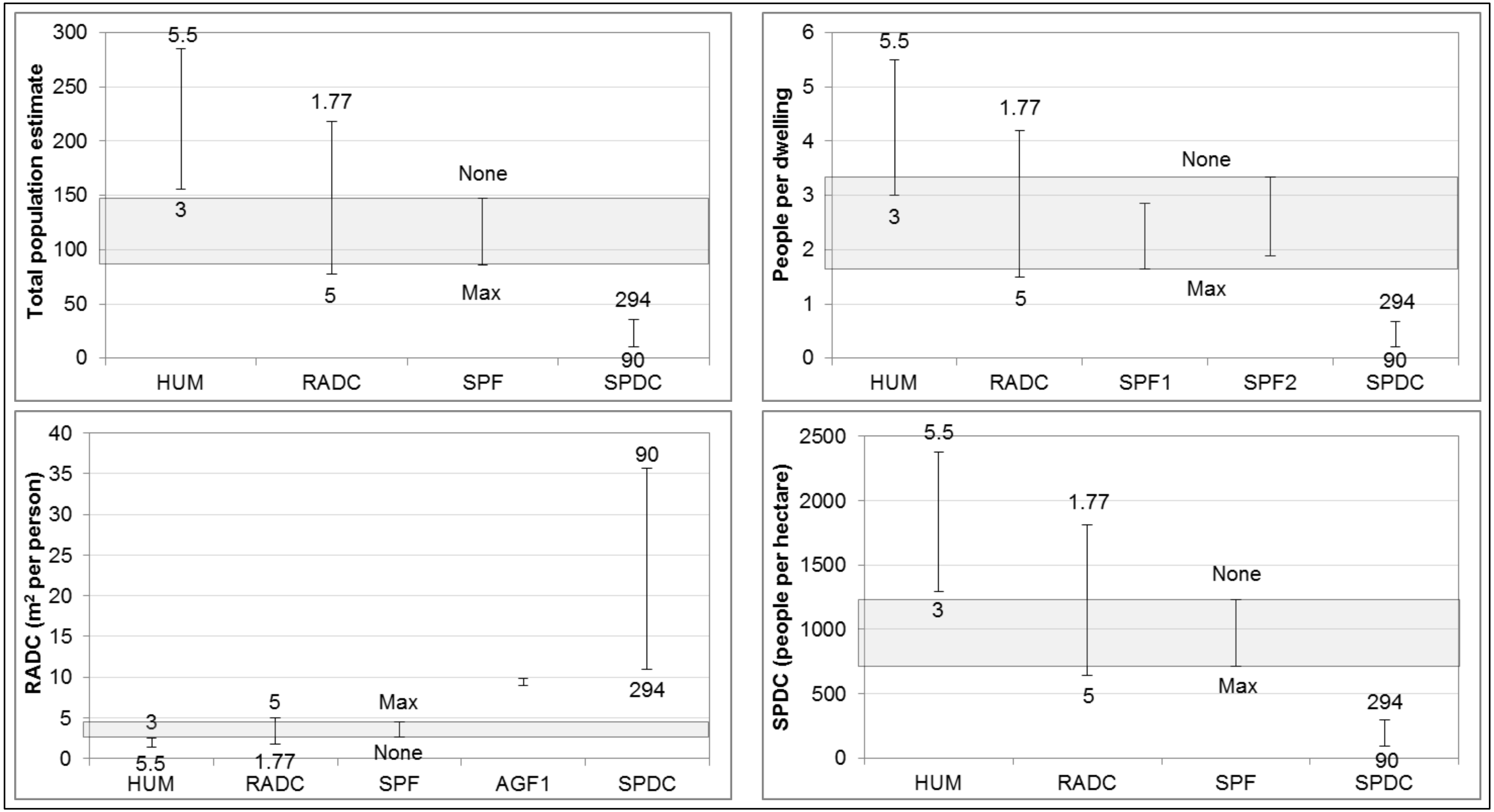


Figure 7.25. Summary of estimates for ‘Ain Abu Nekheileh Phase III.

7.1.9 El-Hemmeh (LPPNB)

Site description

The extent of the LPPNB occupation at el-Hemmeh has been estimated at one hectare (Rollefson 1999) (Table 7.25; Figure 7.26). However, area north of the excavated area indicates discontinuous habitation. Based on this and the topographical restrictions of the site, a reduced extent of 0.8 hectares is utilised in calculations of population size.

Excavation exposed a series of rectilinear, semi-subterranean and multi-storey structures, similar to those at Wadi Hamarash I (Sampson 2013a), Basta (Nissen 2006) and Ba'ja (Gebel and Bienert 1997; Makarewicz *et al.* 2006). Walls were constructed with limestone slabs, double-faced with red and white plaster, whilst floors comprised plaster-coated flat stone slabs over sub-floor channels of the type found at Basta (Nissen 2006), Wadi Hamarash I (Sampson 2013a) and es-Sifiya (Mahasneh 1997; Makarewicz *et al.* 2006, p.185). These channels have been interpreted as representing water management (Goring-Morris and Belfer-Cohen 2010) or ventilation shafts (Kuijt and Goring-Morris 2002, p.409).

Groups of structures may represent residential units comprising a larger and potentially upper storey residential area connected to smaller storage or workshop areas (White 2013, p.70). Four potential residential units are identified (Table 7.26) (Wright 2000; White and Wolff 2012). The presence of thick stone walls, buttresses, inset spaces for roof beams within higher walls, stone stairways and rooms which were only accessible from above all indicate upper storeys.

Table 7.25. Description of LPPNB el-Hemmeh* and refined variables.

Estimated site extent		10,000 m^2 (8,000 m^2 used in calculations)
Assessable area		101.38 m^2
Potential dwellings		4
Environment		On an alluvial fan near perennial watercourse in steep-sided Wadi Hasa
Subsistence		Hunting, gathering, agriculture (wild barley; domesticated emmer and small-seeded legumes); pastoralism (sheep and goats); possible intentional irrigation
Architecture		Rectilinear; thick stone walls, limestone slabs; semi-subterranean and multi-storey; sub-floor channels; plastered interior; residential upper storey; lower storey storage/workshop space; pueblo-style; considerable subdivision and compartmentalisation; considerable remodelling
Economy		Considerable storage facilities; workshops (beads); household-based production, consumption and storage; craft specialisation; important centre for agricultural activities; household inherited agricultural knowledge; established trade networks (imported shell)
Ritual/community organisation		Establish ritual activity (anthropomorphic figurine; burial with burial goods); social differentiation/social status (items of personal adornment; different architectural forms and displays of wealth)
Structural contemporaneity		78%
Refined variables:	HUM	Minimum-average (maximum nuclear family size excluded based on insufficient mean residential floor area (8.66 m^2))
	SPF	None-moderate (maximum excluded based on high frequency of designated storage rooms)
	AGF2	Village and urban

* Wright 2000; Makarewicz and Austin 2006; Makarewicz *et al.* 2006; Makarewicz and Rose 2011; White and Makarewicz 2012; White and Wolff 2012; White 2013.

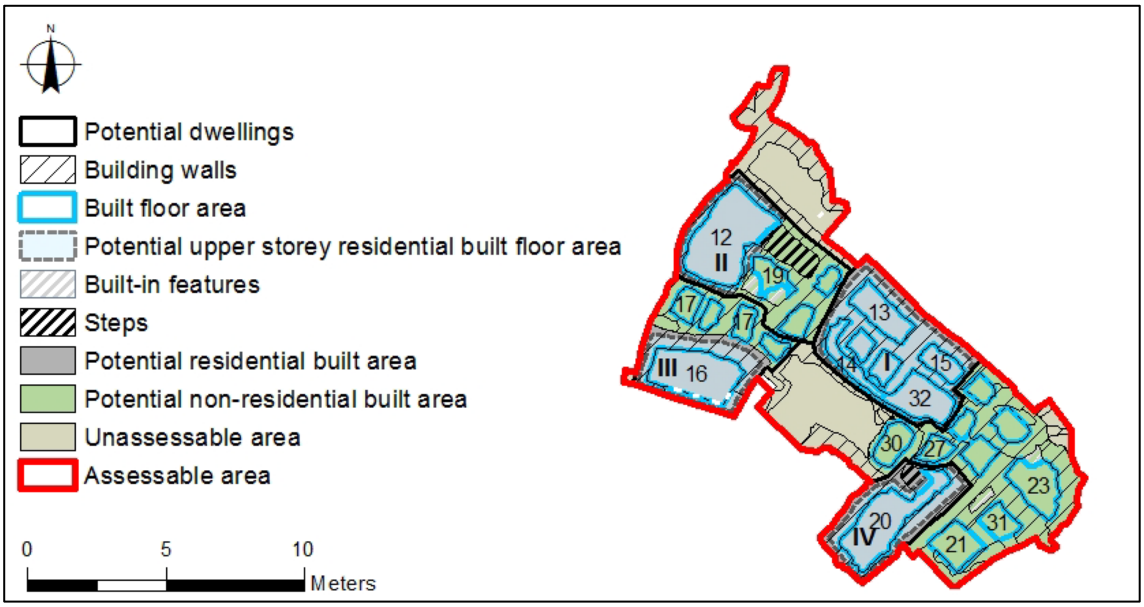


Figure 7.26. Site plan of LPPNB el-Hemmeh (transcribed from Makarewicz and Austin 2006, p.19 and Makarewicz 2010, p.7).

Table 7.26. Residential units identified at LPPNB el-Hemmeh.

Unit	Space	Description	Suggested residential area
1	13	Passageway, probably roofed; huge stone lintel requiring considerable effort for placement supported weight above opening - infers an upper storey; modifications of wall in Space 13; later used as a midden	An upper storey area covering all ground floor spaces
	14	Storage(?); accessed via Space 13; a series of renovations - bins filled and covering with floor; later used as a midden	
	15	Unknown function - probable storage; accessed via Space 13; later used as a midden	
	32	Possible extension of Space 14; additional storage(?).	
2	12	Extremely durable white plaster floor; raised platform 2 x 2 m in western portion; accessed via stairs from Space 19; beneath the top plaster floor: hearth connected to subterranean channel	Space 12 (or an upper storey of comparable size)
	19	Possible courtyard; later filled and had three bins built within the fill; fill of F-27 indicates bead-manufacturing; original access via Space 12	
3	16	Probable access through roof or second-storey; repeated modifications - changed in use four times from active living/working/storage space to a midden; 2.5 m of cultural deposits; extended use life; resembles “Basta House” layout	An upper storey area covering Space 16
	17	Accessible through roof or second-storey; frequent alterations of external walls and partitioning of interior space; two plastered bins, one of which contained an adult skull associated with a cache of burial goods which appeared to have been placed within a basket; anthropomorphic figurine	
4	20	2nd storey evidence; contained subterranean channel; three construction phases; stairway and roof supports; packed earth floor when single storey; when converted to two-storey had plaster floor; groundstone artefacts, complete mammal leg bones and ochre on ground floor suggests use of ground floor as a storage or processing area	An upper storey area covering Space 20

Contemporaneity assessment

The considerable investment in architectural construction, including sub-floor channels, an immensely heavy lintel between Spaces 13 and 15, and huge volumes of storage facilities, indicates a relatively extended occupation span. Almost all structures have been substantially remodelled, re-floored and re-plastered throughout their use-life, with many demonstrating successive stages of active use followed by periods of refuse dumping. Analysis of comparable structures (masonry with considerable maintenance) indicates potential use-life of between 75 and 100 years (see Table 5.7).

Unfortunately, due to insufficient radiocarbon determinations, chronological information regarding phase length and building use-life could not be further refined and a direct contemporaneity value could not be established. Sites that demonstrate the closest comparable architectural features and spatial layout in this investigation all recorded contemporaneity values of around 78% (Beidha Subphase C2, Ghwair I and Wadi Hamarash I). Therefore, this value is also utilised for LPPNB el-Hemmeh.

Previous population estimate

The population of LPPNB el-Hemmeh has previously been estimated at 900 people based on 90 people per hectare and a suggested average total site extent of 10 hectares for LPPNB settlements (Kuijt 2008a). This is almost 10 times the actual estimated extent of LPPNB el-Hemmeh

Population estimates and group size thresholds

The SPF based on limited residential storage provisions indicates a total (adult) population of around 530 to 795 people, around 2.2 to 3.2 people per dwelling, around 2.7 m^2 to four m^2 residential floor area per person and around 530 to 790 people per hectare (Table 7.27; Figure 7.27). This population estimate is considerably lower than the pre-existing estimate (P = 900). This estimate falls at the upper end of the hypothesised group size threshold relating to the adoption of a fully sedentary agro-pastoralist subsistence strategy (P = 100-750). Evidence suggests that inhabitants of LPPNB el-Hemmeh engaged in agricultural and pastoral practices relating to domesticated emmer, legumes, sheep and goats.

The estimate also exceeds the threshold relating to the introduction of mechanisms for reducing scalar stress and promoting social cohesion (P ≥ 150). This is evidenced at LPPNB el-Hemmeh by the possible sectoring of the village into household economic units, more formalised ritual activities and more structured space designated for non-domestic activities (Wright 2000; White and Wolff 2012).

The emergence of more complex society (P ≥ 350), including potential authoritative individuals (P ≥ 500), may be evidenced at LPPNB el-Hemmeh by specialist craft activities and workshops, well-established trade networks, differing structural forms and associated facilities, various items of personal adornment, and differential mortuary treatment, including a unique skull burial with a cache of burial goods (Makarewicz *et al.* 2006, pp.213-215).

Potential evidence exists for innovative farming methods, hypothesised to occur at much higher population levels (P ≥ 3,000). The cultivation of domesticated emmer wheat requires at least 400 mm annual rainfall, suggesting either a significant increase in annual rainfall during the LPPNB or intentional irrigation (White 2013, p.420). It is suggested that cultivation plots were intentionally irrigated and that these plots may have been inherited (White and Wolff 2012, pp.289-294). The occurrence of such innovations in farming methods despite the small population size may indicate that LPPNB el-Hemmeh formed part of a broader group of villages, as is reflected by the extensive trade network.

Table 7.27. Summary of estimates for LPPNB el-Hemmeh.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings: 246.20	*Based on total contemporaneous residential floor area (m^2): 2133.04*	*Based on total site extent (ha): 1*
HUM	738.61-1354.11	3-5.5	1.58-2.89	738.61-1354.11
RADC	426.61-1205.11	1.73-4.89	1.77-5.00	426.61-1205.11
SPF1	532.43-794.74	2.16-3.23	2.68-4.01	532.43-794.74
SPF2[a]	-	2.18-3.04	-	-
AGF1[a]	-	-	3.38-3.6	-
SPDC	90-294	0.37-1.19	7.26-23.7	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:** *None (794.74)*	*Moderate (532.43)*	*Maximum (450.26)*
Naroll's (1962) AGF1		22.10	30.96	35.65
Wiessner's (1974) AGF2	Open settlements	0.02	0.04	0.05
	Village settlements	12.58	18.78	22.21
	Urban settlements	116.53	152.20	170.19

Additional demographic data			Contemporaneous (78%)
Proportion (%) of site comprising:	Built area	79.89	62.31
	Residential built area	41.75	32.57
	Built floor area	61.12	47.67
	Residential floor area	27.35	21.33
Proportion (%) of assessable built area comprising:	Residential built area	52.26	
	Built floor area[b]	76.50	
	Residential floor area	34.23	
Proportion (%) of built floor area comprising residential floor area		44.74	
Mean residential floor area of complete dwellings (m^2)		8.66	

[b] Based on assessable built area (101.24 m^2) and built floor area (77.45 m^2).

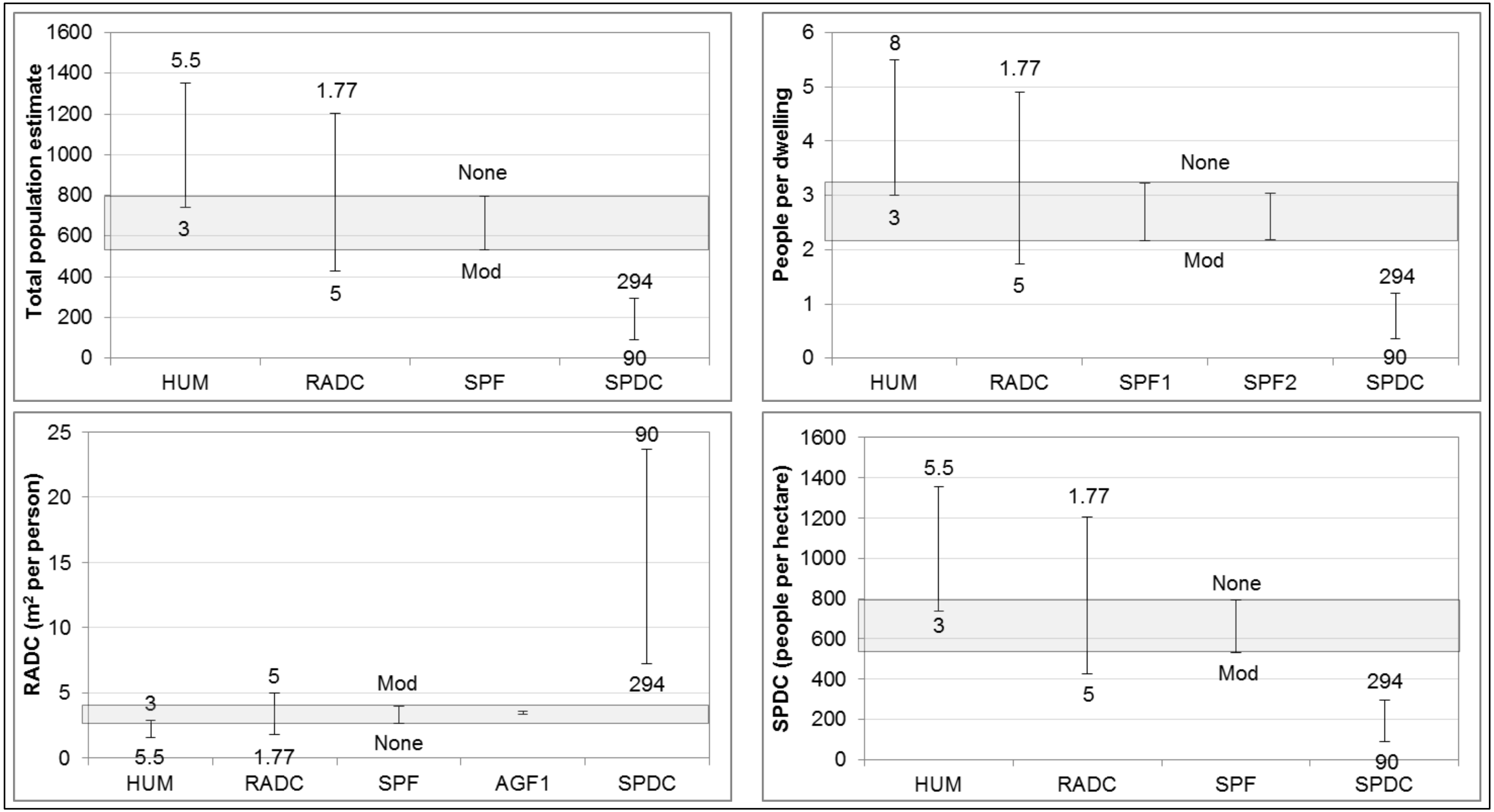


Figure 7.27. Summary of estimates for LPPNB el-Hemmeh.

7.1.10 Basta

Site description

Basta is a very large LPPNB (and possibly PPNC) village in southern Jordan (Table 7.28). Three architectural phases (I-III) are present across three excavation areas (A-C). Area B, Phase II occupation evidence is assessed in detail as the function and grouping of architectural features in the remaining areas and phases are unclear.

Excavation exposed interlocking and adjacent, rectilinear structures above sub-floor channels, which often contained burials. Structures were built on artificial terraces supported by massive retaining walls (surviving up to two metres high). The carefully prepared terraces adjoined and, therefore, the structures on top of them could not be extended or externally modified, indicating that structure size and layout was predetermined. The uniformity in layout and construction in Area B suggests a single building episode (Nissen 2006, p.173). Walls, floors, door frames, lintels and passageways were constructed with limestone. It is suggested that roofs consisted of a layer of organic material over a grid of wooden beams, coated with a thick layer of mud (Nissen 2006, pp.138-139). Reconstructions indicate that structures were completely roofed except for an access or ventilation point in the central area. Plaster and colourful decoration were a common feature (Nissen 2006, pp.134-135).

Most structures in Area B conform to the distinctive “Basta house” architectural form (Houses I-VII). These comprise a large central space surrounded by small rooms attached to at least one side. Smaller compartments, regarded as storerooms, usually cover no more than one square metre and were accessed from the central space via window-like openings (Nissen 2006, p.138). House VIII is a unique form for Area B, comprising a large space (Room 1) connected to a series of smaller compartments on the southern and western sides and two long parallel rooms (Rooms 2 and 3) on the northern side (Nissen 2006, p.134). It is unclear whether this house was utilised for residential or non-residential purposes. As such, House VIII is unassessed.

The lack of obvious evidence for living or sleeping space has ignited debate about upper storey rooms. Hemsley (2008, p.294) estimated the population of House I based on an upper storey area covering the entire ground floor plan. She estimated that up to 46 people could have slept in this space. Clearly dwelling units of this size would produce an excessive population density. Alternate scenarios including partial upper storey areas produced dwelling occupant ranges of six to 13 people, which are more consistent with the ranges derived for MPPNB Jericho and Basta Area A in the same investigation (Hemsley 2008, p.297). This estimate supports the current theory that large, compartmentalised LPPNB dwellings accommodated large nuclear or extended family units (Rollefson and Kafafi 2013, pp.11-13).

The majority of archaeological evidence, including hearths and localised densities of lithic-production waste, points to single storey structures in which larger central areas formed the main residential area, whilst roofs may have provided additional space for living, sleeping and working (Nissen 2006, p.139). Gebel (2006, p.68) proposes that the larger space occupied by Basta houses may have made upper storeys unnecessary. Nissen (2006, p.177) supports this notion, suggesting that upper storeys, where present, would probably have consisted of one or two rooms on one part of the building. It is highly plausible that upper storeys may have been located in spaces backing onto the walls of other structures built on higher terraces. For example, House III was built on a higher terrace compared to adjoining Houses I and VIII. A physical inspection of the site in 2016 indicated that the north-western portion of House I may have contained an upper storey area adjacent to House III. High walls and buttresses between Rooms 1 to 3 in House VIII indicate that the majority, if not all, of this structure may have been two-storey.

In this investigation, four scenarios relating to the location of residential space within the lower and/or upper storey are explored. In these scenarios, residential floor area is located in (1) the ground floor central room/s only; (2) an upper storey covering the smaller compartments only; (3) the ground floor central room/s and a partial upper storey area on one side of the structure covering areas which allow for floor area of at least two meters width/length and on the upslope side of the building where possible; and (4) a full upper storey (Figure 7.28).

Given the exclusion of Areas A and C in this assessment, it is necessary to discuss to what degree Area B represents the total site and whether a reduced total site extent should be utilised in calculations of population size. The total site extent of Basta has been estimated at between 12 and 14 hectares (Kuijt 2000, p.81). It is suggested that the architectural density evident in the excavated areas could not have extended across the entire site. Gebel *et al.* (2006b, pp.216-217) compared the structure and layout of Basta to terraced, pueblo-style settlements in modern Afghanistan and Algeria in which clusters of compounds or living quarters are separated by abandoned or disused areas, and walkways (i.e. in Area B, Rooms 22-23 are interpreted as a walkway or corridor). The differences in architectural layout between Areas A (Figure 7.29) and B indicate sectoring of the settlement into 'neighbourhoods', potentially based on different socio-economic status. This is suggested based on the well-planned, larger and more elaborate house layout in Area B as opposed to the haphazard distribution of structures in Area A. To account for disused space between these ‘neighbourhoods’ and differential use of space in different areas, the total site extent is reduced to 10 hectares in calculations of population size to avoid overestimating the population.

Table 7.28. Description of Basta Phase II* and refined variables.

Estimated site extent		120,000-140,000 m^2 (100,000 m^2 used in calculations)
Assessable area		302.51 m^2
Potential dwellings		6
Environment		On SE facing slope above Wadi Basta amongst prehistoric steppe forest in a semi-arid region
Subsistence		Hunting, gathering, agriculture (domesticated barley, wheat, emmer and lentil); pastoralism (caprines and cattle)
Architecture		Rectilinear; stone walls; single or two-storey?; "Basta house" form; master plan; sub-floor channels; considerable subdivision and compartmentalisation
Economy		Dwelling-based production, processing, consumption and storage; storage bins within some residential floor area; craft specialisation (figurines; jewellery; tools); possible centre for stone tool manufacture; extensive trade and exchange of precious materials (turquoise; Anatolian obsidian) and exotic items (mother of pearl amulets; shaped green stone pendants; stone rings)
Ritual/community organisation		Well-established ritual (sub-floor burials; skulls surrounded by stones; figurines; possible ceramic horns); social differentiation/social status (items of personal adornment and identification); sectoring into neighbourhoods
Structural contemporaneity		60.47%
Refined variables:	SPF	Scenario 1: none-moderate (maximum excluded based on high frequency of designated storage rooms) Scenarios 2-4: moderate (none removed to account for space used for possible access of ground floor storage/workshop areas from upper storey)
	AGF2	Village and urban

* Kuijt 2000; Twiss 2001; Gebel 2006; Gebel *et al.* 2006a; 2006b; Nissen 2006; Hemsley 2008; Makarewicz and Tuross 2009.

Figure 7.28. Site plan of Basta Phase II, Area B. Four scenarios: residential floor area in (1) ground floor central room/s; (2) upper storey above smaller compartments; (3) ground floor central room/s and partial upper storey; (4) full upper storey (transcribed from Nissen 2006, pp.164-169 and Gebel *et al.* 2006b, Insertion: Top Plan Area B).

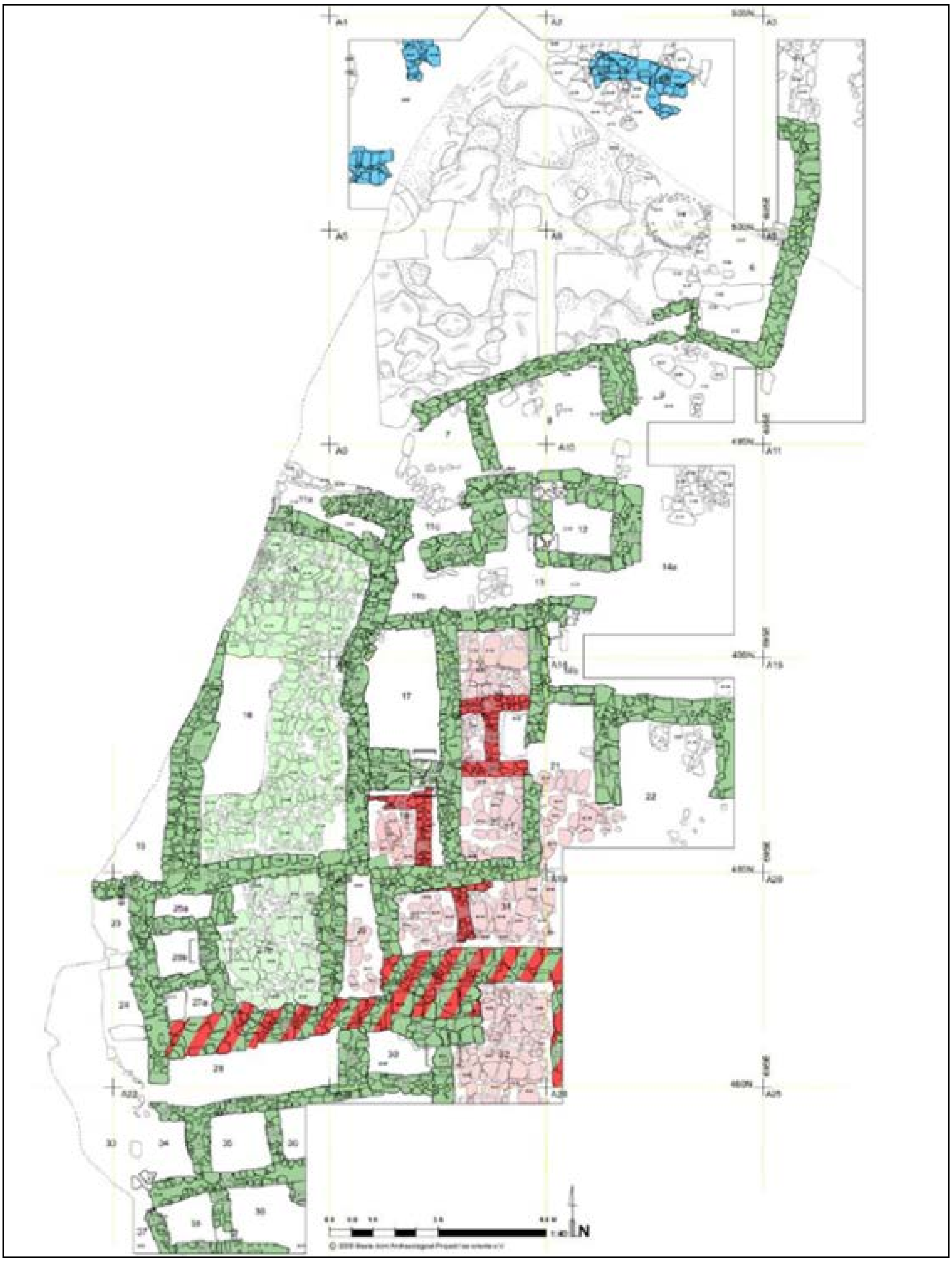


Figure 7.29. Ground plan of Basta Area A. Phase II features highlighted in green (Phase I: blue; Phase III: red). There is a small “Basta house” in the southwest portion (Gebel *et al.* 2006b, Insertion: Top Plan Area A).

Contemporaneity assessment

Sufficient radiocarbon dates (*n* = 12) exist for Bayesian chronological modelling. Several dates have been assigned to Phases I (*n* = 2) and II (*n* = 3). A further date is assigned to Phase I in this investigation based on its location and context (GrN 14537: sourced from the northern section of Area A in cultural debris above bedrock). It is unclear whether the remainder of dates belong to architectural Phase II or III due to the lack of chronostratigraphic order, probably resulting from disturbance processes. However, the calibrated date ranges indicate two distinct phases. For the purposes of Bayesian chronological modelling, dates belonging to the earlier and later phases were assigned to Phases II and III, respectively.

As the relationship between phases is unclear and there is no further information regarding the internal ordering of dates within each phase, a contiguous phase model was constructed with three phases (I-III). Each phase included one building with more than one date (Phase I: Area B, Room 24; Phase II: Area B, Building V, Room 1; Phase III: Area A, Room 39) enabling estimates of building use-life. Within each phase, an individual building phase model was constructed for these buildings, with all other loci placed within separate phase models.

A χ^2 test (df = 11, T = 209.042 (5% 19.7)) indicated that at least one date does not conform to the stratigraphic sequence. The initial run of the chronological model highlighted one date with poor agreement (KIA 30845b: A = 1.5). The removal of this date from subsequent χ^2 testing (df = 10, T = 205.602 (5% 18.3)) indicated further divergent dates, which were not identified in a subsequent run of the chronological model.

The final model produced a start date of *7,790 to 7,380 cal BC* and an end date of *7,040 to 6,640 cal BC*, with a span of up to 1,050 years (Table 7.29; Figure 7.30). The maximum span would suggest occupation from the later MPPNB to the beginning of the PPNC. Modelled transition dates for Phases I and II (*7,540-7,350 cal BC*) and Phases II and III (*7,140-6,890 cal BC*) produced span estimates of up to 100 years for Phase I; up to 430 years for Phase II; and up to 230 years for Phase III. The relative length of these spans is consistent with the archaeological evidence for Phase II as the major occupation phase.

Removal of the date with poor agreement from Phase I prevented reconstruction of a span estimate for Room 24 (estimated at up to 130 years in the initial model). The span for Phase II: Building V, Room 1 was estimated at up to 260 years; whilst the span for Phase III: Room 39 was estimated at up to 150 years. The lengthy spans reflect the exceptional durability of the structures at Basta, which made prominent use of large limestone slabs to create interconnecting walls and used massive terrace walls for their external boundaries (Nissen 2006, pp.135-136). These spans exceed building use-life estimates derived from archaeological, ethnographic and experimental research of masonry structures with considerable maintenance evidence (75 to 100 years) (see Table 5.7). It is possible that span estimates have been inflated due to the impact of old wood on radiocarbon distributions (Wicks *et al.* 2016). However, the spans produced may still be suitable for establishing a contemporaneity value. This investigation assesses Phase II only. Phase II length (430 years) and building use-life (260 years) span estimates produce a contemporaneity value of 60.47%. This relatively low contemporaneity value is consistent with the theory that groups of structures may have been separated by considerable abandoned and disused area (Gebel *et al.* 2006b, pp.216-217).

Previous population estimate

The population of LPPNB Basta has previously been estimated at 900 people based on 90 people per hectare and a suggested average of 10 hectares for LPPNB settlements (Kuijt 2008a). An alternative estimate of between 1,260 and 4,116 people was based on 90 and 294 people per hectare and an estimated total site extent of 14 hectares (Kuijt 2000). A third estimate of 3,293 people was based on population estimates of the largest LPPNB settlements (Kuijt 2000). A further estimate of 839 to 2,789 people was based on a total site extent of 9.8 hectares and density coefficients of 35 m^2 site area per person (van Beek's 1982) to 116.3 m^2 site area per person (Jacobs 1979) (Campbell 2009, p.199).

Table 7.29. Modelled boundary dates and span estimates for Basta. Highlighted date removed from 2nd run.

					1st run			2nd run		
Building/Room	**Lab reference**	**Area**	**Material**	**Radiocarbon date range (cal BC) (95%)**	**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=27.6 Aoverall=28.9*		**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=106.4 Aoverall=105.5*	
						A	*C*		*A*	*C*
Start Phase I					*7680-7350*		*98.6*	*7790-7380*		*98.4*
(north)	GrN 14537	A	?	7600-7170	7570-7360	126.8	99.7	7590-7400	122.8	99.9
Room 24	KIA 30845a	B	CH	7590-7380	7580-7360	87.5	99.7	7580-7450	102.7	99.9
	KIA 30845b	B	H	7170-6410	7550-7350	1.5	99.7			
	Span Area B: Room 24				**0-130**		**99.9**			
Span Phase I					**0-140**		**99.9**	**0-100**		**100**
Transition Phases I/II					*7530-7330*		*99.7*	*7540-7350*		*99.9*
Building V, Room 1	KIA 30848a	B	CH	7520-7190	7480-7190	92.2	99.9	7490-7190	98	99.8
	KIA 30848b	B	H	7480-7090	7450-7080	104	99.9	7460-7080	102.6	99.8
	Span Area B: Building V, Room 1				**0-250**		**99.9**	**0-260**		**99.8**
Room 11b	KIA 30842	A	CH	7520-7300	7480-7190	92.1	99.9	7490-7190	98.2	99.7
Room 7	GrN 14538	A	CH	7320-7050	7310-7060	99.6	99.9	7310-7050	99.4	99.8
Room 33	KIA 30846	B	CH	7300-6840	7290-7030	96.1	99.9	7290-7030	96.9	99.8
Span Phase II					**160-420**		**99.9**	**180-430**		**99.8**
Transition Phases II/III					*7140-6890*		*99.7*	*7140-6890*		*99.7*
Room 39	KIA 30843a	A	CH	7060-6770	7050-6820	107	99.5	7050-6820	106.9	99.7
	KIA 30843b	A	H	7050-6770	7050-6820	106.4	99.5	7050-6820	106.3	99.7
	Span Area A: Room 39				**0-150**		**99.9**	**0-150**		**99.9**
Building I, Room 1	KIA 30844	B	CH	7050-6700	7050-6800	108.8	99.5	7050-6800	109.1	99.7
Building VIII	KIA 30847	B	CH/H	7030-6640	7050-6760	79.7	99.4	7050-6760	80.3	99.6
Span Phase III					**0-230**		**99.7**	**0-230**		**99.7**
End Phase III					*7040-6650*		*97*	*7040-6640*		*96.5*
Span Phases I-III					**…-980**		**98.4**	**460-1050**		**96.8**

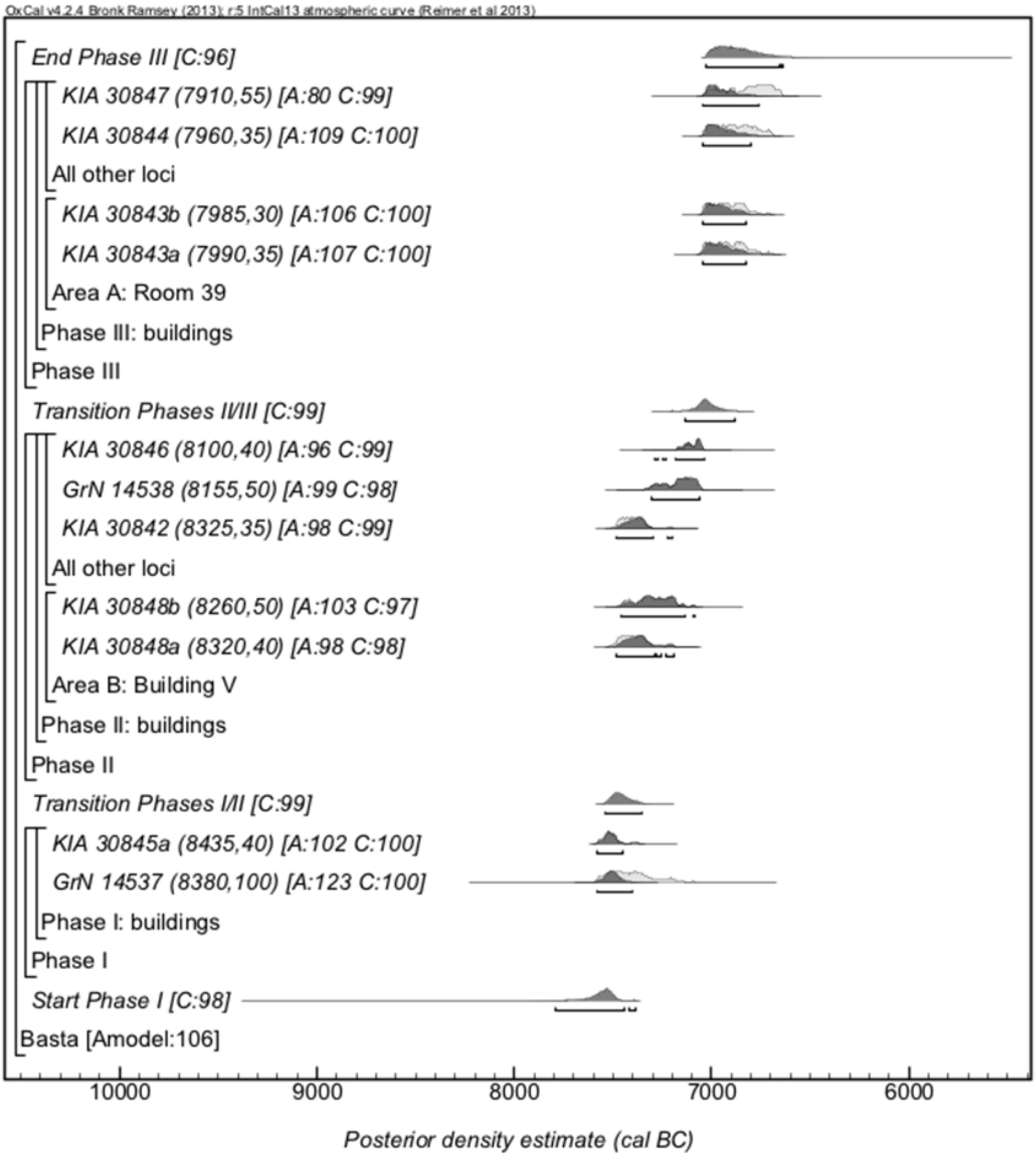


Figure 7.30. Modelled posterior density estimates for Basta (2nd run: divergent date removed).

Population estimates and group size thresholds

The results of each scenario were assessed to determine which should be included in the final analysis. SPF estimates based on Scenario 4 (P = 10,140-12,410) were considered excessive, as these would produce seemingly unsustainable density values (780-1,000 people/ha) (Appendix C.1). Conversely, estimates based on Scenario 1 (P = 3,250-4,920), although plausible, appear to be too conservative, particularly when converted to people per dwelling (2.7-4.2) and population density (250-380 people/ha).

Similar estimates were derived for Scenarios 2 (P = 6,460-7,830; 5.4-6.5 people/dwelling; 500-600 people/ha) and 3 (P = 5,690-7,850; 4.8-6.5 people/dwelling; 440-600 people/ha). The final analysis is based on the slightly more conservative Scenario 3 estimates. The concentration of domestic features and artefacts in the central rooms and the variable evidence for upper storeys indicates that this may be the most plausible scenario.

The SPF based on moderate residential storage provisions indicates a total (adult) population of around 5,690 to 7,850 people, around 4.8 to 6.6 people per dwelling, around 2.9 m^2 to four m^2 residential floor area per person and around 440 to 600 people per hectare (Table 7.30; Figure 7.31). This population estimate exceeds the pre-existing estimate range (P = 1,260-4,116) and is comparable to the current population size estimate for the largest known PPN settlement, Çatalhöyük (P = 5,000-8,000; c. 14 ha) (Matthews 1996; Cessford 2005; Hodder 2006; Düring 2007).

The estimate exceeds all hypothesised group size thresholds discussed in this investigation, including those for the adoption of a fully sedentary agro-pastoralist subsistence strategy (P = 100-750); the introduction of mechanisms for reducing scalar stress and promoting social cohesion (P ≥ 150); the emergence of more complex society including authoritative individuals (P ≥ 350 and 500, respectively); and the adoption of innovative farming methods (P ≥ 3,000).

At Basta, these developments are evidenced by agro-pastoralist practices relating to domesticated barley, wheat, emmer, lentil, sheep, goat and cattle; intentional irrigation and floodplain cultivation; intensive fodder provisioning strategies for goat management; and the use of animals for both meat and dairy products (Makarewicz and Tuross 2009; Makarewicz 2013, p.256). In addition, Basta demonstrates evidence for intra-village sectoring into neighbourhoods and economically independent household units, with compartmentalisation in dwellings potentially aimed at alleviating stress associated with social crowding (Gebel *et al.* 2006b, pp.216-217; Nissen 2006). Further, there is evidence for well-established ritual activities, specialist craft activities, extensive trade networks and variable mortuary practices, including variable association of burials with grave goods (Nissen 2006). The distinct architectural differences between Areas A and B, and the clear sectioning of the village into 'neighbourhoods' may provide further evidence for socio-economic differentiation.

At this population size, Basta could be considered to represent a 'town' rather than 'village' settlement (P ≥ 400). However, archaeologists are reluctant to use the term 'town' for settlements dating to this period, due to a lack of some major urban characteristics, such as evidence for vastly increased productivity, incorporation into a broader political system and the presence of many places of entertainment.

In a recent study of epigenetic characteristics of teeth and skulls at Basta, Alt *et al.* (2013) identified evidence for intentional endogamy, the process of marrying only within a community. Such demographically stable residential communities are hypothesised to occur in settlements of at least 475 people. The earliest examples are usually only documented within urbanised, hierarchical communities that emerged in Mesopotamia, Egypt and the Indus Valley around 3,000 years ago (Bittles and Black 2010). Endogamy at Basta was interpreted as a deliberate strategy for segregation based on familial relationships, ensuring inherited wealth and status, and access to restricted resources, such as agricultural land (Alt *et al.* 2013, p.6). This increasing social differentiation may have induced rival authority figures, potentially resulting in political stratification (expected to occur at $P \geq 1,500$).

Table 7.30. Summary of estimates for Basta Phase II: Scenario 3.

Method	**Total population**	**People per dwelling**	**RADC (m^2/person)**	**SPDC (people/ha)**
		Based on total number of contemporaneous dwellings: 1199.37	*Based on total contemporaneous residential floor area (m^2): 22981.40*	*Based on total site extent (ha): 13*
HUM	3598.1-9594.92	3-8	2.40-6.39	276.79-738.07
RADC	4596.28-12983.84	3.83-10.83	1.77-5.00	353.56-998.76
SPF1	5692.53-7853.94	4.75-6.55	2.93-4.04	437.89-604.15
SPF2[a]	-	6.55	-	-
AGF1[a]	-	-	2.87-3.02	-
SPDC	1170-3822	0.98-3.19	6.01-19.64	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (10527.20)	*Moderate (6773.23)*	*Maximum (5403.69)*
Naroll's (1962) AGF1		28.63	41.51	50.20
Wiessner's (1974) AGF2	Open settlements	0.00	0.00	0.00
	Village settlements	12.35	19.19	24.06
	Urban settlements	270.56	363.04	422.04

Additional demographic data			
			Contemporaneous (60.47%)
Proportion (%) of site comprising:	Built area	76.92	46.52
	Residential built area	41.40	25.03
	Built floor area	53.64	32.44
	Residential floor area	29.23	17.68
Proportion (%) of assessable built area comprising:	Residential built area	53.82	
	Built floor area [b]	69.73	
	Residential floor area	38.00	
Proportion (%) of built floor area comprising residential floor area		54.50	
Mean residential floor area of complete dwellings (m^2)		26.30	

[b] Based on assessable built area (302.51 m^2) and built floor area (210.95 m^2).

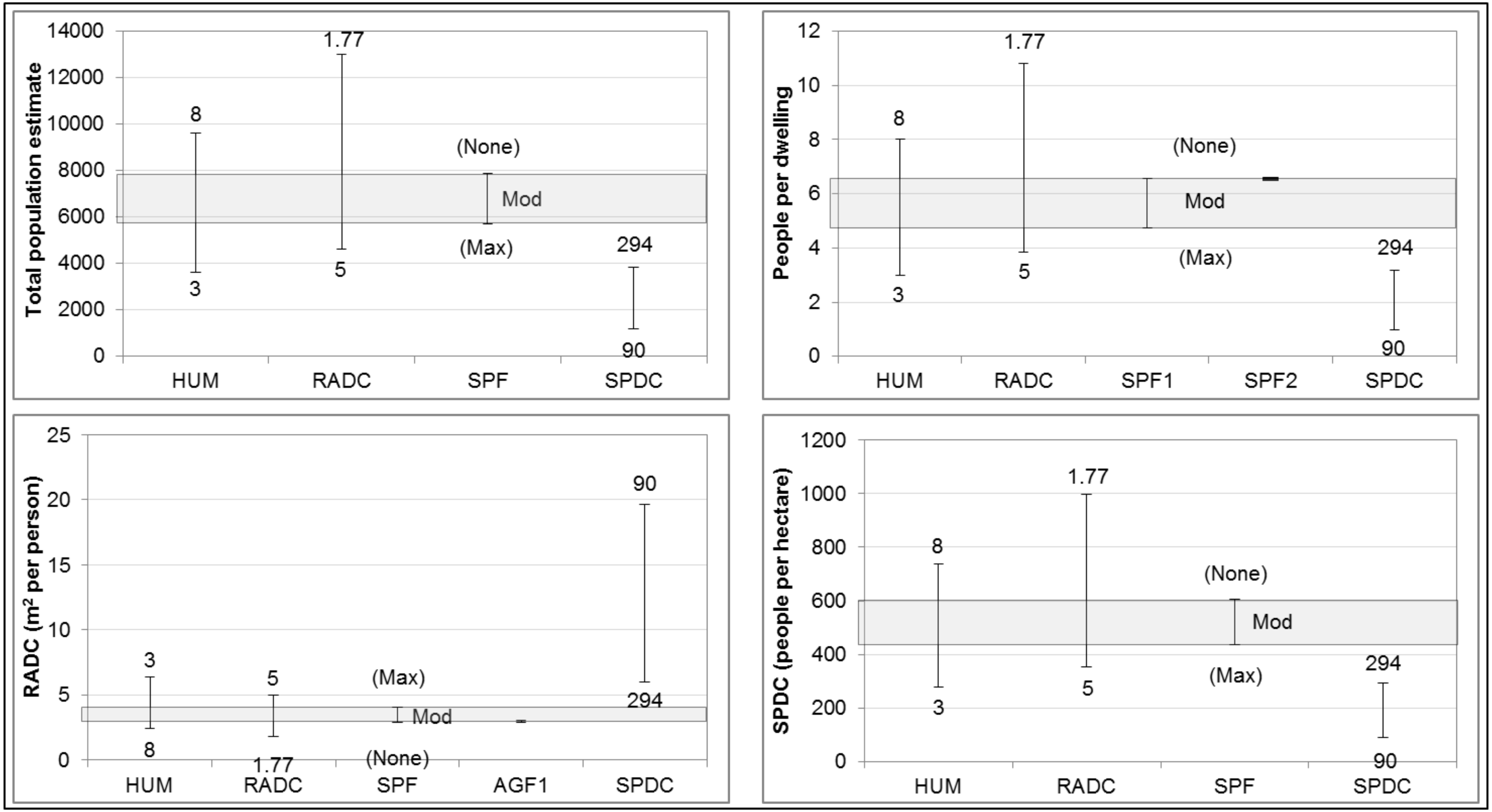


Figure 7.31. Summary of estimates for Basta Phase II: Scenario 3.

7.1.11 Ba'ja

Site description

Ba'ja is a LPPNB village in southern Jordan (Table 7.31; Figures 7.32-7.33). Investigations were conducted across multiple areas (A-I) with major excavations in Areas B, C and D. Excavations revealed a densely-packed, pueblo-style settlement, with the majority of residential area located in the eastern portion on the upper slope (Areas B-D) (Figure 7.34). Spatial distribution of architectural, agricultural and open areas varied throughout the site (Bienert and Gebel 2004). Based on this spatial patterning and inspection of the potential habitable area, the estimated total site extent of 1.2 to 1.5 hectares (Gebel 2003, p.18) is reduced to 0.9 hectares for calculations of population size.

The residential units comprised terraced, two-storey and split-level architecture with smaller potential storage or workshop rooms on the ground floor, and larger potential residential rooms usually on the upper storey (Figure 7.35). Thick stone walls and twin strengthening buttresses supported upper storeys and roofs made of hard mortar-like material and gravel, which were utilised for additional activities including sandstone ring workshops (Kinzel 2013). No doorways were uncovered and outer walls of residential units contained no windows, indicating that access to all rooms was via the ceilings. Bienert and Gebel (2004, p.141) compare these units to a "communal fortified complex, not easy to enter and easy to control". The interior of these residential units appear to have formed private sectors, whilst rooftops served as public and perhaps communal spaces (Bienert and Gebel 2004, p.141).

In all areas, building units are considered to be predominantly residential (Bienert and Gebel 2004; Gebel 2006; Kinzel 2013). Kinzel (2013, p.120) identifies six residential units in Area B North and four in Area C (Table 7.32). Bienert and Gebel (2004, p.126) identify a further two potential residential units in Area D. It is suggested that ground floor rooms or spaces built on bed-rock were not utilised areas but, rather, spaces resulting from the construction of substructures for supporting first floors on the sloping ground (Bienert and Gebel 2004). Where bedrock is utilised as a wall boundary, these tend to lack wall dressings and are suggested to have a non-residential function.

Table 7.31. Description of Ba'ja* and refined variables.

Estimated site extent		12,000-15,000 m^2 (9,000 m^2 used in calculations)
Assessable area		486.69 m^2
Potential dwellings		12
Environment		On slope within an elevated, intra-montane basin surrounded by rock formations and steep slopes – defensive position
Subsistence		Hunting, gathering, probable agriculture (emmer), pastoralism (domesticated goat, sheep); may have harvested rain water as there was no nearby water source; designated storage rooms within structures; storage rooms accessed via residential floor area; potential additional on floor storage
Architecture		Rectilinear; thick stone walls; hard mortar roofs; multi storey; pueblo-style; residential upper storey and large rooms; storage/workshop space on both upper and lower storey; plastered interior; considerable subdivision and compartmentalisation; considerable remodelling
Economy		Dwelling-based production, processing and consumption (household autonomy); craft specialisation (jewellery; tools); sandstone ring production centre; household production of rings for export and trade; imported materials (pendants, rings and buttons made of greenstone, mother of pearl and Red Sea molluscs); part of a local settlement system with nearby "mega-sites" al-Baseet and Basta
Ritual/community organisation		Established ritual (anthropomorphic figurines; burial with burial goods; collective burials; red pigment on bones and painting on burial chamber wall; ritual-related imagery); social differentiation/social status (items of personal adornment; different architectural forms; differing burial goods); possible sectoring into neighbourhoods
Structural contemporaneity		78%
Refined variables:	SPF	Moderate (none excluded due to area required to access storage rooms via residential floor area; maximum excluded based on high frequency of designated storage rooms)
	AGF2	Village and urban

* Gebel 2002; 2003; 2006; Bienert and Gebel 2004; Gebel and Hermansen 2004; Gebel and Kinzel 2007; Purschwitz and Kinzel 2007; Kinzel 2013.

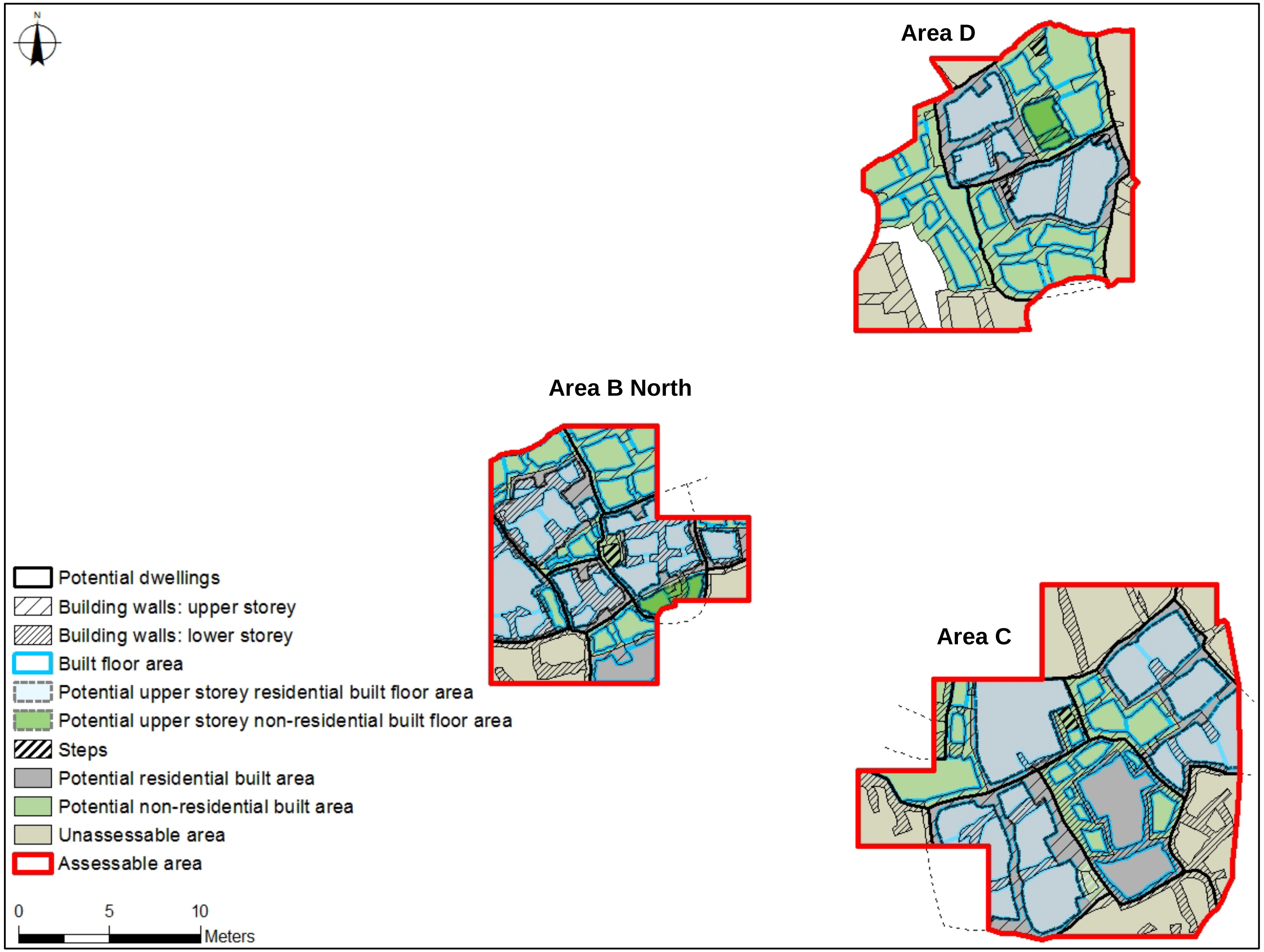


Figure 7.32. Site plan of Ba'ja Areas B North, C and D (transcribed from Gebel and Hermansen 1999, p.19 and Kinzel 2013, pp.406-444).

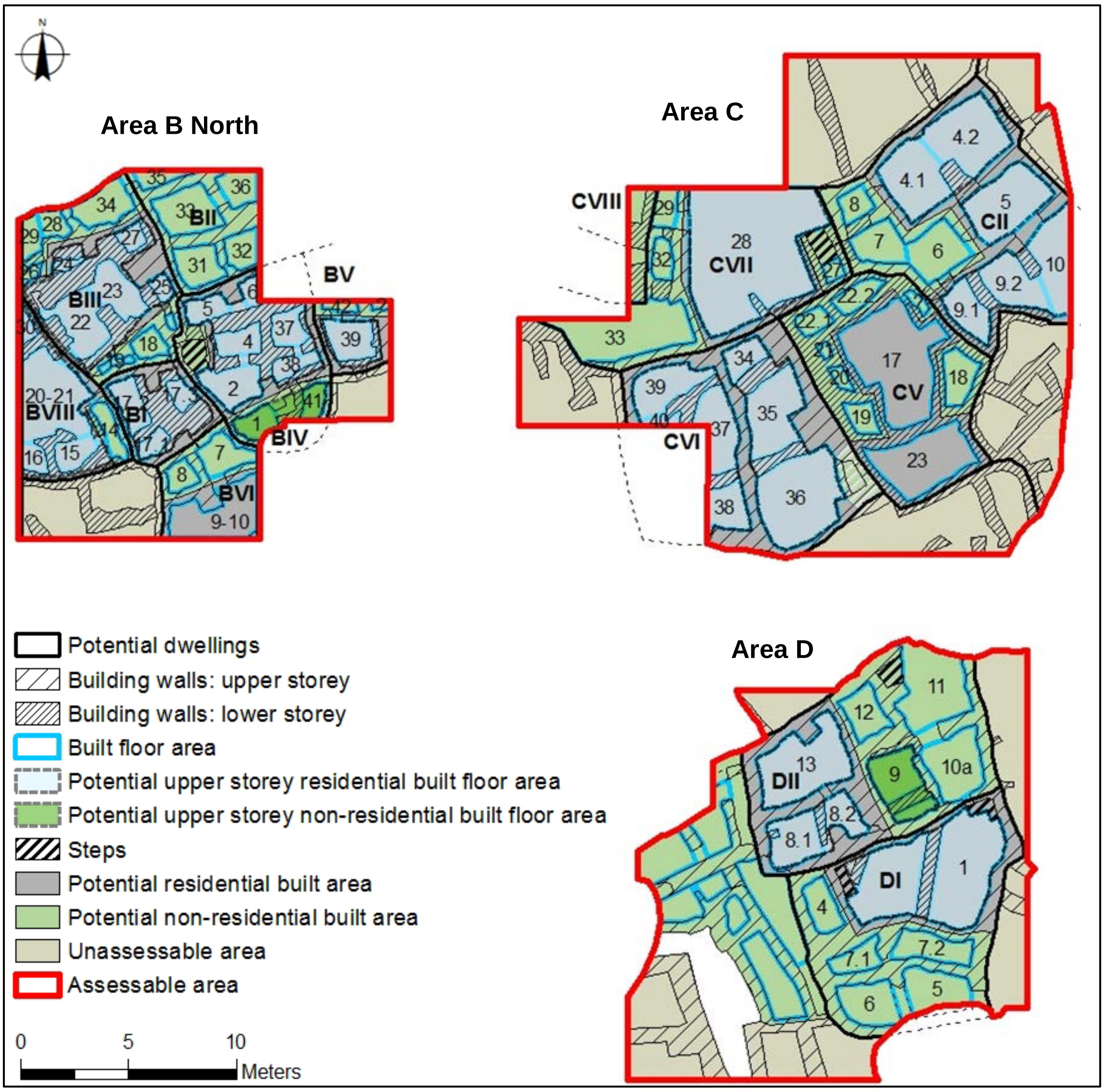


Figure 7.33. Enlarged plans of Ba'ja Areas B North, C and D (transcribed from Gebel and Hermansen 1999, p.19 and Kinzel 2013, pp.406-444).

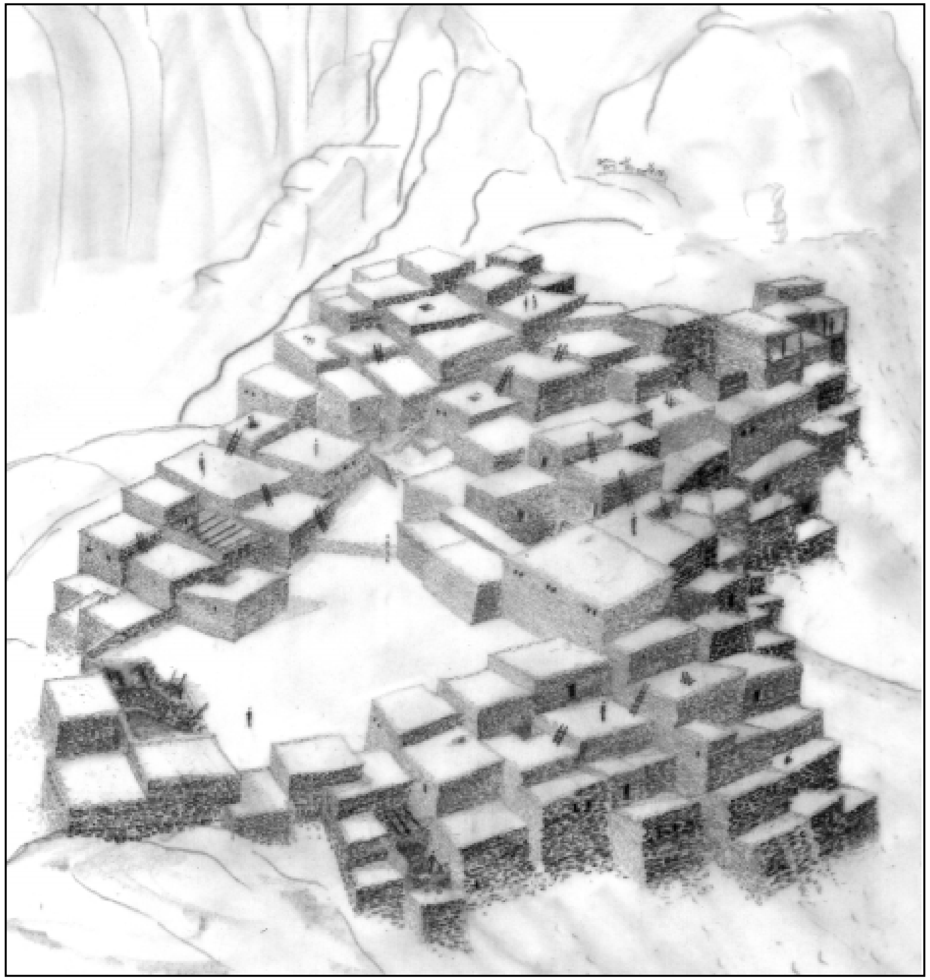


Figure 7.34. Reconstruction of pueblo-style settlement at Ba'ja showing open, communal area between Area B North and South (Kinzel 2004, p.21).

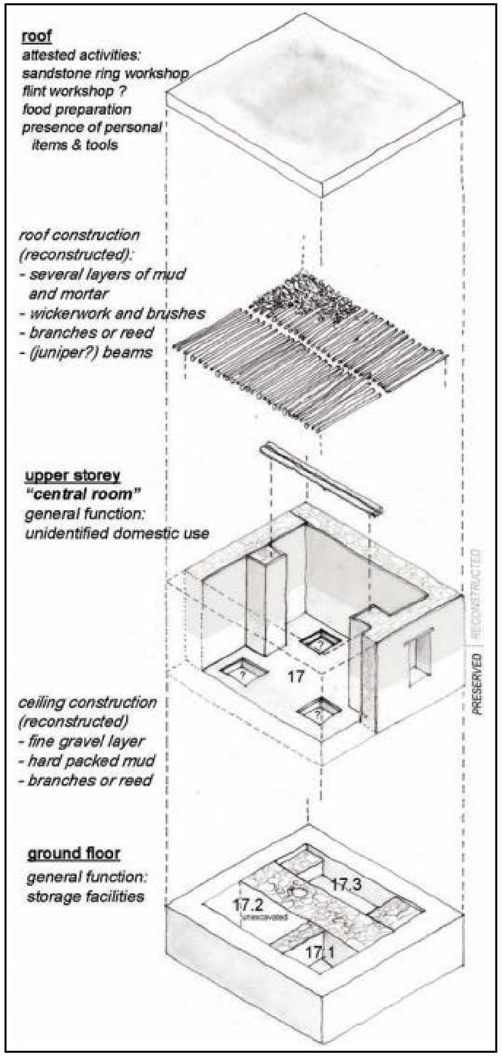


Figure 7.35. Reconstruction of residential Unit BI in Ba'ja Area B North (Purschwitz and Kinzel 2007, p.30).

Table 7.32. Potential residential units identified in Ba'ja Areas B North, C and D (Kinzel 2013).

Area	Unit	Room/Space	Description	Suggested residential area
B North	BI	17	Large upper storey room with twin buttresses resting on basement walls and supporting the roof	Room 17
		17.1-3	Basement rooms accessed from above; red plaster floor; Space 17.3 had a renewed floor	
		Rooftop	Sandstone ring workshop	
	BIII	22-23	Large upper storey room with twin buttresses	Rooms 22-23
		18-19, 22-29, 34	Basement workshop and storage rooms (celt workshop: Room 23)	
	BIV	?	Large upper storey room (not numbered) with twin buttresses	Upper storey area above Rooms 2, 4-6, 37-38
		1-2, 4-6, 37-38, 41	Basement rooms accessed via Room 2 from upper storey; red stained plaster floor in Room 2	
		3	Staircase in Space 3 from upper storey to basement Room 2	
		Rooftop	Sandstone ring workshop	
	BV	39	Basement and upper storey level	Room 40
		40, 42	Rooms accessed to the north and south	
		Rooftop	Sandstone ring workshop	
	BVI	9-10	Large room probably with twin buttresses	Rooms 9-10
		7-8	Smaller rooms – possible storage or work areas	
	BVIII	20-21	Larger rooms; possibly two-storey	Upper storey area above Rooms 15-16, 20-21, 30
		14	Very small storage rooms accessed from above	
		15-16, 30	Small, basement rooms	
C	CII	4-10	Basement and upper storey levels	Upper storey area above Rooms 4-5, 9-10
	CV	17, 23	Large, central rooms	Rooms 17, 23
		18-22	Smaller surrounding compartments – possible storage	
	CVI	34-40	Basement and upper storey levels	Upper storey area above Rooms 34-40
	CVII	28	Large central room with basement and upper level	Upper storey area above Room 28
		29, 32	Small basement rooms	
		27	Staircase and landing	
		33	Possible corridor, courtyard or room	
D	DI	1	Large central room	Room 1
		4-7	Smaller surrounding compartments	
	DII	8-9, 13	Basement and upper level rooms	Upper storey area above Rooms 8-11, 13
		10-11	Possibly ground floor rooms of single storey section	
		12	Small storage room accessed via steps from Room 11	

Contemporaneity assessment

Structures comprised multi-storey, masonry construction, with thick, interconnecting stone walls. Considerable evidence for remodelling, including blocked wall openings, raised floors, new floors and the addition of supporting walls indicates extended use-life. Archaeological, ethnographic and experimental research of comparable structures (masonry with moderate-considerable maintenance) indicates potential use-life of 50 to 100 years (see Table 5.7). Structural composition is similar to the buildings found at Beidha Subphase C2, which were estimated as spanning around 70 years.

Radiocarbon dates were sourced from three loci (3, 18 and 20). As there was only one date per structure, building use-life estimates could not be refined. A χ^2 test (df = 2, T = 20.172 (5% 6)) indicated at least one divergent date. This date was not identified in the chronological model. Removal of the earliest and latest date in turn from subsequent χ^2 tests indicated that radiocarbon date Bin 5123 was probably divergent. This date was removed from the final run of the model, which indicated a start date of *7,840 to 6,660 cal BC,* an end date of *6,900 to 5,770 cal BC*, and a span of up to 250 years (Table 7.33; Figure 7.36).

The end date spans into the Pottery Neolithic period, well beyond the suggested end of the occupation indicating that this estimate may be too broad. Indeed, evidence for only one domestic phase in Area B North and a maximum of two phases in Area B South and Area C, as well as minimal evidence for superpositioning or disuse of structures throughout, indicates a relatively restricted occupation span. In addition, large rubble accumulations, twisted walls and subsidence presumably resulting from high energy events such as floods and earthquakes suggest that a catastrophic event may have prematurely terminated the occupation (Gebel and Kinzel 2007, p.29).

General evidence for one domestic phase and rapid abandonment suggests that there may have been a high degree of structural contemporaneity. Unfortunately, the available chronological information is insufficient for reconstruction of a precise contemporaneity value. Analysis of settlements with comparable structures and spatial layout (Beidha Subphase C2, Ghwair I and Wadi Hamarash I) has produced relatively high contemporaneity values (78%). This value is also considered suitable for Ba'ja.

Previous population estimate

The population of Ba'ja has previously been estimated at between 400 and 500 people based on an hypothesised number of 50 to 60 dwellings occupied by families of 8 to 10 people (Gebel and Hermansen 1999, p.19).

Table 7.33. Modelled boundary dates and span estimates for Ba'ja. Highlighted date removed from 2nd run.

Lab reference	**Locus**	**Material**	**Radiocarbon date range (cal BC) (95%)**	**1st run**			**2nd run**		
				Posterior density estimate range (cal BC) (95.4%)	**Indices** *Amodel=90.6* *Aoverall=88.7*		**Posterior density estimate range (cal BC) (95.4%)**	**Indices** *Amodel=111.8* *Aoverall=109.4*	
					A	*C*		*A*	*C*
Start Ba'ja				*8270-7030*		*97.6*	*7840-6660*		*97*
Bin 5123	20	CH: Juniperus; Pistacia	7180-7040	7180-6860	103.2	99.7			
Bin 5036	3	CH: Juniperus + indet	7030-6640	7040-6650	92.5	99.2	7030-6640	108.3	99.5
Bin 5035	18	CH: Juniperus	7030-6630	7040-6640	85.1	99.3	7030-6640	104.9	99.6
End Ba'ja				*7020-5550*		*95.6*	*6900-5770*		*97.4*
Span Ba'ja				**50-470**		**99.1**	**0-250**		**99.8**

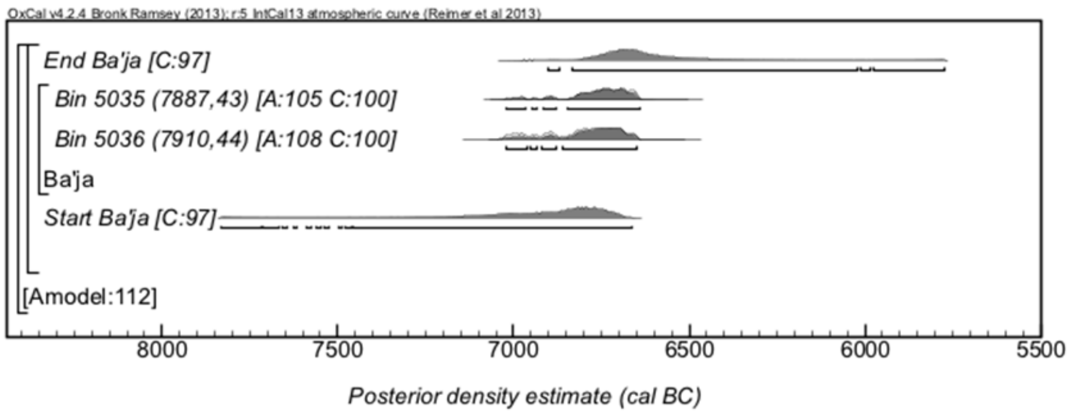


Figure 7.36. Modelled posterior density estimates for Ba'ja (2nd run: divergent date removed).

Population estimates and group size thresholds

The SPF based on moderate residential storage provisions indicates a total (adult) population of around 585 to 610 people, around 3.4 to 3.5 people per dwelling, around four m^2 to 4.2 m^2 residential floor area per person and around 650 to 680 people per hectare (Table 7.34; Figure 7.37). This population estimate is slightly higher than the pre-existing estimate of 400 to 500 people. This estimate exceeds the minimum hypothesised group size thresholds relating to the adoption of a fully sedentary agro-pastoralist subsistence strategy ($P \geq 100$); the introduction of mechanisms for reducing scalar stress and promoting social cohesion ($P \geq 150$); and the emergence of more complex society ($P \geq 350$), including authoritative individuals ($P \geq 500$).

These developments are evidenced at Ba'ja by agro-pastoralist practices relating to potentially domesticated emmer and domesticated goat and sheep (von den Driesch *et al.* 2004), including possible intentional harvesting of rain water (Gebel 2004b, p.28). In addition, evidence exists for intra-village sectoring into neighbourhoods and economically independent household units engaged in specialist production of luxury objects for export, including sandstone rings (Wright 2000; Bienert and Gebel 2004). Ba'ja also demonstrates highly formalised ritual activities and well-structured space for non-domestic activities. These aspects all indicate some degree of labour and social differentiation. Although not a "mega-site" itself, Ba'ja is considered to reflect many aspects of such a community (Gebel 2002).

Table 7.34. Summary of estimates for Ba'ja.

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 173.09	*Based on total contemporaneous residential floor area (m^2): 2461.74*	*Based on total site extent (ha): 1.35*
HUM	519.26-1384.7	3-8	1.78-4.74	576.96-1538.56
RADC	492.35-1390.81	2.84-8.04	1.77-5.00	547.05-1545.35
SPF1	583.81-609.81	3.37-3.52	4.04-4.22	648.67-677.56
SPF2[a]	-	3.37	-	-
AGF1[a]	-	-	3.18	-
SPDC	121.5-396.9	0.7-2.29	6.2-20.26	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (912.92)	*Moderate (596.81)*	*Maximum (487.53)*
Naroll's (1962) AGF1		25.20	36.05	42.74
Wiessner's (1974) AGF2	Open settlements	0.02	0.04	0.06
	Village settlements	14.79	22.62	27.69
	Urban settlements	143.42	190.41	217.89

Additional demographic data			
			Contemporaneous (78%)
Proportion (%) of site comprising:	Built area	65.36	50.98
	Residential built area	38.21	29.81
	Built floor area	58.03	45.27
	Residential floor area	23.38	18.24
Proportion (%) of assessable built area comprising:	Residential built area	58.47	
	Built floor area[b]	88.79	
	Residential floor area	35.77	
Proportion (%) of built floor area comprising residential floor area		40.28	
Mean residential floor area of complete dwellings (m^2)		13.48	

[b] Based on assessable built area (477.15 m^2) and built floor area (423.66 m^2).

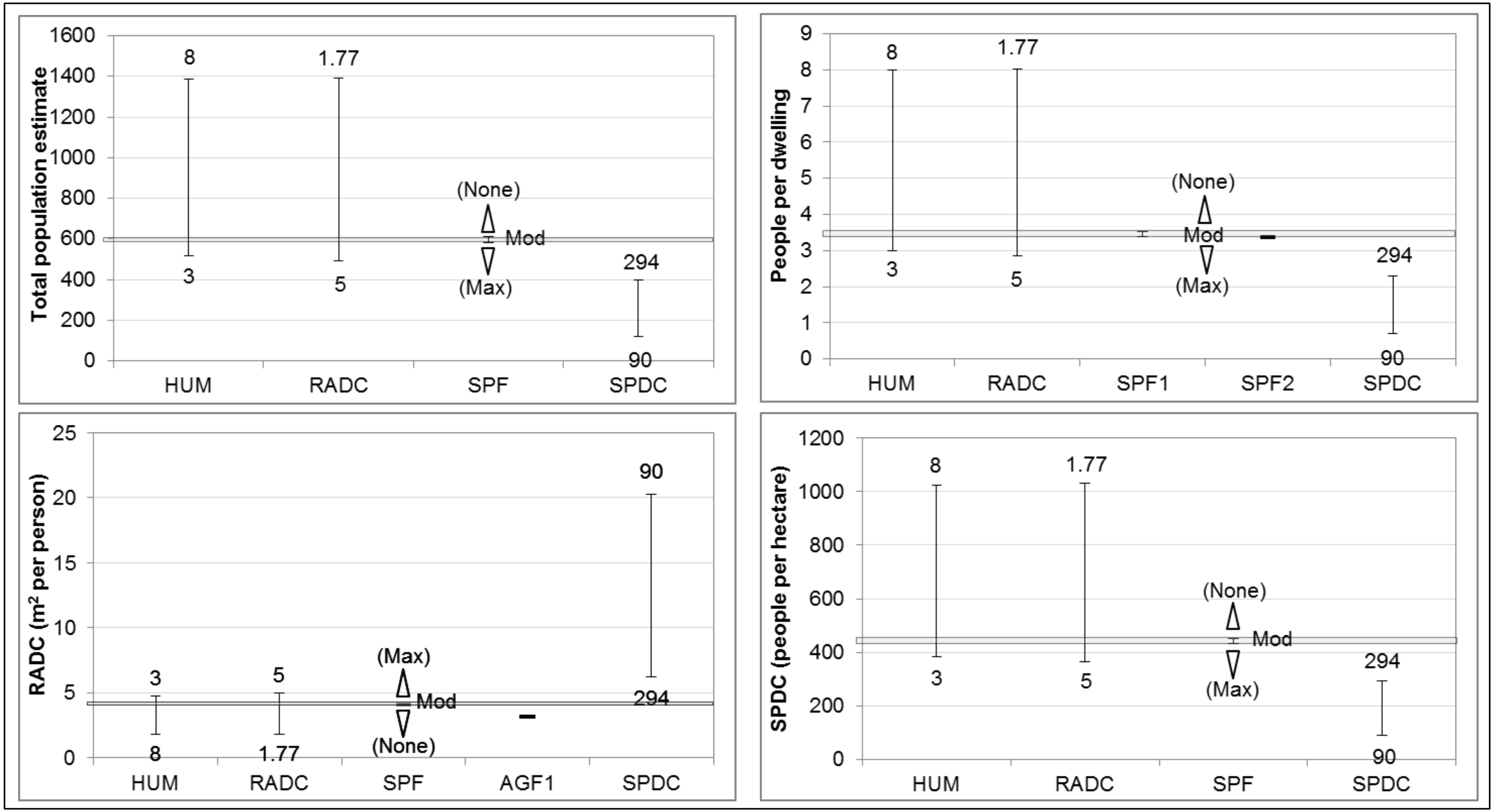


Figure 7.37. Summary of estimates for Ba'ja. Values in brackets for the SPF indicate direction of estimate if the formula for none and maximum storage were included in the final estimate range.

7.2 Summary of micro-level estimates

This section summarises estimates of people per dwelling; residential floor area and settlement population density coefficients (RADC and SPDC); re-calculated initial growth indices for Naroll's (1962) and Wiessner's (1974) AGF; various area proportions; and the mean residential floor area of complete dwellings. Results are based on estimate ranges derived from applicable SPF (Table 7.36; Figure 7.38).

7.2.1 People per dwelling

People per dwelling estimate ranges varied considerably from a minimum of 0.9 to 1.5 people at PPNA el-Hemmeh to a maximum of 3.9 to 6.6 people at Basta. The estimated range derived for PPNA el-Hemmeh is unique to this dataset, in that it is the only estimate that indicates that dwellings may have been predominantly inhabited by individuals, possibly as part of an extended family unit, as originally proposed by Bar-Yosef (1998). More restricted unit sizes were also estimated for Beidha Subphases A2 (1.7-2.5 people) and B2 (1.5-2.2 people), and 'Ain Abu Nekheileh (1.7-2.9 people). Byrd (2005a) suggested that nuclear families formed the predominant dwelling unit in all phases at Beidha and it is commonly argued that nuclear families typified the dwelling unit throughout the PPN (Sweet 1960; Wright 1969; Antoun 1972; Watson 1978; 1979; Kramer 1979; 1982; Aurenche 1981; van Beek 1982; Finkelstein 1990; Zorn 1994) (see Table 4.1). These low estimates do not appear to support this generalisation. However, it must again be emphasised that SPF population estimates are based on adult human heights and may be increased following consideration of children.

7.2.2 Residential floor area per person

Estimates of residential floor area per person (RADC) demonstrated limited variation from a minimum of 2.3 m^2 to 3.3 m^2 at PPNA el-Hemmeh, which had the smallest estimated mean residential floor area of complete dwellings (4.83 m^2) to a maximum of four m^2 to five m^2 at Netiv Hagdud, which had the largest mean residential floor area (21.33 m^2). However, for all other settlements, there is limited correlation between RADC and residential floor area.

The estimated RADCs compare well with those derived for comparable sites in other investigations (2.16-4.55 m^2 per person) (Hill 1970; Clarke 1974; Kramer

1979; Hayden *et al.* 1996) and the range utilised in RADC population estimates in this investigation (1.77-5 m^2).

7.2.3 People per hectare

Conversion of total population estimates derived from the SPDC method into population and dwelling unit sizes in the assessable area indicated that the commonly utilised density values (SPDCs) are too low for PPN central and southern Levantine villages (Table 7.35). The minimum SPDC (90 people/ha) resulted in average dwelling unit sizes of less than one person for all sites except Netiv Hagdud (1.33 people) and Ghwair I (1.13 people). The average SPDC (150 people/ha) produced average dwelling unit sizes of less than one person for nine of the 15 sites, with just over one person for three sites (Wadi Hamarash I: 1.5; Beidha Subphase C2: 1.23; Ba'ja: 1.17), and around two people for the remaining three sites (Netiv Hagdud: 2.22; Ghwair I: 1.88; Basta: 1.63).

Application of the maximum SPDC (294 people/ha) produced average dwelling unit sizes of:

- less than one person for PPNA el-Hemmeh and 'Ain Abu Nekheileh;
- around one person for Nahal Oren, Beidha Subphases A1, A2 and B2, and LPPNB el-Hemmeh;
- around two people for Gilgal I, Shkārat Msaied, Beidha Subphase C2 and Ba'ja;
- around three people for Wadi Hamarash I and Basta; and,
- around four people for Netiv Hagdud and Ghwair I.

Even the maximum commonly utilised SPDC produces seemingly insufficient dwelling unit size estimates for most sites. This is particularly evident when assessing estimates for sites with high density, highly compartmentalised, two-storey dwellings, considerable ground floor storage space and potentially large upper storey residential areas that are generally thought to have been occupied by larger nuclear or even extended family units (i.e. Beidha Subphase C2, LPPNB el-Hemmeh, Basta and Ba'ja) (Gebel and Hermansen 1999; Byrd 2005a; Rollefson and Kafafi 2013).

Dwelling unit sizes produced via this method were similar to the minimum final estimates derived from the SPF for Netiv Hagdud (based on SPDC: 4.36; minimum based on SPF: 4.3), Ghwair I (based on SPDC: 3.68; minimum based on SPF: 3.8) and Wadi Hamarash I (based on SPDC: 2.94; minimum based on SPF: 3). These sites contained very low estimated proportions of contemporaneous residential floor area in assessable area resulting in low dwelling unit size estimates via the SPF method. In addition, Netiv Hagdud and Ghwair I recorded the two lowest structural densities.

Population density coefficients derived from SPF population estimates ranged widely from a minimum of around 290 to 360 people per hectare at Netiv Hagdud to a maximum of around 710 to 1,230 people per hectare at ‘Ain Abu Nekheileh. The majority of SPDC estimates far exceed the density coefficients previously utilised for estimating PPN Levantine village populations (90-294 people/ha) (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009). The upper end of SPDCs estimated for ‘Ain Abu Nekheileh, PPNA el-Hemmeh (686-1,006 people/ha) and LPPNB el-Hemmeh (666-993 people/ha) are comparable to the upper density limit suggested for early agricultural villages (1,000 people/ha) (Fletcher 1981). If children were factored into SPF population estimates, the subsequent SPDCs would further exceed those derived in this analysis.

High population density largely reflects high structural density resulting from interconnected, clustered, and often multi-storey structures; and high proportions of contemporaneous residential floor area, particularly within settlements of predominantly curvilinear architecture where the majority of structures were identified as residential.

Table 7.35. Population estimates based on the SPDC method converted to population and dwelling unit size in the assessable area.

Site name	Total population based on commonly utilised SPDCs			Proportion of site assessable (%)	Population in assessable area based on commonly utilised SPDCs			Contemporaneous dwellings in assessable area	People per dwelling in assessable area based on commonly utilised SPDCs			People per dwelling estimates based on SPF		Built area in site area (structural density) (%)	Contemporaneous residential floor area in assessable area (%)
	People/ha				*People/ha*				*People/ha*						
	90	*150*	*294*		*90*	*150*	*294*		*90*	*150*	*294*	***Min***	***Max***		
Nahal Oren	4.5	7.5	14.7	65.27	2.94	4.9	9.59	8	0.37	0.61	1.2	**2.1**	**3.5**	54.69	22.66
Gilgal I	36	60	117.6	5.37	1.93	3.22	6.32	3.6	0.54	0.9	1.75	**2.6**	**4.5**	51.39	16.58
Netiv Hagdud	67.5	112.5	220.5	7.12	4.8	8.01	15.69	3.6	1.33	2.22	4.36	**4.3**	**5.3**	31.70	14.39
El-Hemmeh (PPNA)	9	15	29.4	6.15	0.55	0.92	1.81	4.5	0.12	0.2	0.4	**1.1**	**1.5**	54.72	22.73
Shkārat Msaied	18	30	58.8	34	6.12	10.2	19.99	10.4	0.59	0.98	1.92	**2.8**	**4.9**	58.13	18.69
Beidha (A1)	9	15	29.4	13.22	1.19	1.98	3.89	2.86	0.42	0.69	1.36	**2.8**	**4.1**	65.65	20.99
Beidha (A2)	18	30	58.8	14.68	2.64	4.4	8.63	6.75	0.39	0.65	1.28	**1.8**	**2.5**	57.21	14.85
Beidha (B2)	18	30	58.8	30	5.4	9	17.64	15.02*	0.36	0.6	1.17	**1.6**	**2.2**	57.21	14.14
Ghwair I	119.25	198.75	389.55	4.41	5.26	8.76	17.18	4.67	1.13	1.88	3.68	**3.8**	**5.7**	48.23	12.10
Wadi Hamarash I	45	75	147	24.99	11.25	18.74	36.73	16	0.9	1.5	2.94	**3.0**	**4.4**	63.16	11.33
‘Ain Abu Nekheileh	10.8	18	35.28	11.28	1.22	2.03	3.98	5.85	0.21	0.35	0.68	**1.8**	**2.8**	95.46	32.13
Beidha (C2)	27	45	88.2	31.92	8.62	14.36	28.15	11.67	0.74	1.23	2.41	**4.1**	**6.1**	59.35	16.77
El-Hemmeh (LPPNB)	90	150	294	1.27	1.14	1.9	3.73	3.12	0.37	0.61	1.19	**2.2**	**3.1**	79.89	21.33
Basta	1170	1950	3822	0.3	3.54	5.9	11.56	3.63	0.98	1.63	3.19	**4.8**	**6.6**	76.92	17.68
Ba'ja	121.5	202.5	396.9	5.41	6.57	10.95	21.46	9.36	0.7	1.17	2.29	**3.4**	**3.5**	65.36	18.24

* Based on Beidha Subphase A2 proportions due to depletion of Subphase B2 evidence.

7.2.4 Initial growth indices for the allometric growth formulae

Naroll's (1962) AGF1 re-calculated

Indices re-calculated for Naroll's (1962) AGF1 varied considerably from a minimum of 6.9 to 11.1 for Nahal Oren to a maximum of 36.6 to 48.1 for Basta. There is a clear distinction between the AGF1 index ranges for settlements with predominantly curvilinear architecture (min *a* = 6.9-16.2; max *a* = 9.8-22.7) and those with predominantly rectilinear architecture (min *a* = 16.2-36.6; max *a* = 23.2-48.1). This reflects the fact that Naroll's formula was based predominantly on large villages with agglomerated, rectilinear architecture. Sites with indices comparable to Naroll's original index (*a* = 21.7) demonstrated similar architectural features to those included in Naroll's analysis (Ghwair I: 17.4-25; Wadi Hamarash I: 19.3-27.4; Beidha Subphase C2: 16.2-23.2). Sites that recorded the lowest indices (Nahal Oren; PPNA el-Hemmeh: 7.1-9.8; Shkārat Msaied: 8.7-14.7; Beidha Subphases A1: 8-11.3, and A2/B2: 11.3-15.5; 'Ain Abu Nekheileh: 9.7-15.3) comprised curvilinear architecture, whilst sites which recorded the highest indices (LPPNB el-Hemmeh: 22.1-31; Basta; Ba'ja: 35.4-36.7) comprised very high density, pueblo-style architecture. The highest index, achieved for Basta, reflects the considerably larger estimated site extent (12-14 ha) and population (P = 5,690-7,850).

Interestingly, the mean AGF1 re-calculated index achieved in this investigation (*a* = 18.89) is similar to Naroll's original index (*a* = 21.7). The similarity between these two means supports both Naroll's original conclusions and the potential reliability and accuracy of the population and total built floor area estimates utilised to re-calculate this index in this investigation.

Wiessner's (1974) AGF2 open, village and urban

All sites included in this analysis are considered village settlements. Village initial growth indices ranged from a minimum of 8.1 to 14 for 'Ain Abu Nekheileh to a maximum of 28 to 35 for Netiv Hagdud.

Sites with curvilinear architecture and considerable open space were considered potential open settlements. Open initial growth indices ranged from a minimum of 0.00 (Basta) to a maximum of 0.27 to 0.84 (Nahal Oren). Higher open indices were derived for settlements that conformed most closely to the open settlement type (Nahal Oren; Shkārat Msaied: 0.09-0.31; Beidha Subphases A1: 0.13-0.3, A2: 0.15-0.32 and B2: 0.16-0.34). The lowest open indices were produced for sites containing high density, multi-storey, rectilinear structures that clearly do not conform to this type (Basta; LPPNB el-Hemmeh: 0.02-0.04; Ba'ja: 0.04; Ghwair I: 0.04-0.08).

Sites with rectilinear architecture and multi-storey structures were considered potential urban settlements. Urban initial growth indices ranged from a minimum of 41 to 59 for Nahal Oren to a maximum of 329 to 408 for Basta. The index derived for Basta, which probably represents the only real urban settlement, is considerably higher than that of all other sites.

7.2.5 Area proportions

Proportions of contemporaneous residential built area and residential floor area in site area range from a minimum of 17.15% and 11.33%, respectively, at Wadi Hamarash I to a maximum of 54.57% and 32.13%, respectively, at 'Ain Abu Nekheileh. The percentages recorded for 'Ain Abu Nekheileh are considerably higher than all other sites. This reflects the extremely high proportion of built area and the high proportion of residential structures within that area. Conversely, the percentages derived for Wadi Hamarash I are notably lower than other sites. This reflects the considerable open area and non-residential built space.

The proportion of built floor area in site area ranges from a minimum of 23.98% at Netiv Hagdud to a maximum of 61.12% at LPPNB el-Hemmeh. Sites with the highest percentages contained substantial upper storey floor areas (LPPNB el-Hemmeh; Beidha Subphase C2: 49.67%; Basta: 53.64%; Ba'ja: 58.03%) or had very limited open area between structures ('Ain Abu Nekheileh: 53.97%).

The proportion of residential floor area in built floor area ranges from a minimum of 39.73% at Wadi Hamarash I to a maximum of 100% at Netiv Hagdud, where all structures were considered potential dwellings. In general, sites with agglomerated, rectilinear architecture and those that occur later in the PPN sequence produced lower percentages (Ghwair I: 53.26%; Wadi Hamarash I; Beidha Subphase C2: 43.4; LPPNB el-Hemmeh: 44.74; Basta: 54.5; Ba'ja: 40.28). This reflects the greater allocation of built space for non-residential purposes at these sites.

Table 7.36. Summary of micro-level estimates.

Site	Total population	People per dwelling	RADC	Mean residential floor area of complete dwellings (m^2)	SPDC	AGF1 index	AGF2 open index	AGF2 village index	AGF2 urban index	Contemporaneous residential area in site area (%)		Area proportions (%)	
										Built	*Floor*	*Built floor area in site area*	*Residential floor area in built floor area*
Nahal Oren	24-43	2-3.5	2.6-4.7	9.6	487-861	6.9-11.1	0.27-0.84	11.6-20.5	41-59	36.95	22.66	32.76	86.47
Gilgal I	157-287	2.3-4.7	2.3-4.2	12.77	392-717	13.6-22.7	0.05-0.16	13.9-25.5	91-138	20.97	16.58	40.01	69.1
Netiv Hagdud	215-268	4.2-5.3	4-5	21.33	286-357	16.2-19.6	0.1-0.16	28-35	180-209	19.02	14.39	23.98	100
El-Hemmeh (PPNA)	69-101	0.9-1.5	2.3-3.3	4.83	686-1006	7.1-9.8	0.01-0.21	9.9-14.6	46-60	35.87	22.73	34.57	87.66
Shkārat Msaied	80-149	2.6-4.9	2.5-4.7	13.46	402-745	8.7-14.7	0.09-0.31	13.4-24.9	71-107	36.73	18.69	29.47	79.29
Beidha (A1)	57-86	2.7-4.2	2.4-3.7	11.56	573-864	8-11.3	0.13-0.3	11.6-17.4	51-67	40.45	20.99	34.22	85.88
Beidha (A2)	79-116	1.7-2.5	2.6-3.8	7.26	395-578	11.3-15.5	0.15-0.32	17.3-25.3	84-109	29.84	14.85	29.77	66.54
Beidha (B2)	76-111	1.5-2.2	2.6-3.7	6.52	382-553	11.3-15.5	0.16-0.34	18.1-26.2	87-111	*			
Ghwair I	399-612	3.8-5.8	2.6-4	15.14	399-612	17.4-25	0.04-0.08	21.6-33.2	184-244	19.21	12.1	29.21	53.26
Wadi Hamarash I	147-223	2.9-4.5	2.6-3.9	12.22	293-445	19.3-27.4	0.1-0.23	22.5-34.1	136-180	17.15	11.33	36.56	39.73
‘Ain Abu Nekheileh	86-148	1.7-2.9	2.6-4.5	7.98	713-1231	9.7-15.3	0.05-0.16	8.1-14	43-62	54.57	32.13	53.97	91.59
Beidha (C2)	141-216	3.9-6.4	2.3-3.6	17.15	469-719	16.2-23.2	0.06-0.15	13.9-21.3	83-111	27.83	16.77	49.67	43.4
El-Hemmeh (LPPNB)	532-795	2.2-3.2	2.7-4	8.66	666-993	22.1-31	0.02-0.04	12.6-18.8	117-152	32.57	21.33	61.12	44.74
Basta	5693-7854	4.8-6.6	2.9-4	26.3	438-604	36.6-48.1	0.00	16.6-22.8	329-408	25.03	17.68	53.64	54.5
Ba'ja	584-610	3.4-3.5	4-4.2	13.48	649-678	35.4-36.7	0.04	22.1-23.1	188-193	29.81	18.24	58.03	40.28

* Beidha Subphase B2 proportions not assessed as largely based on Subphase A2 proportions.

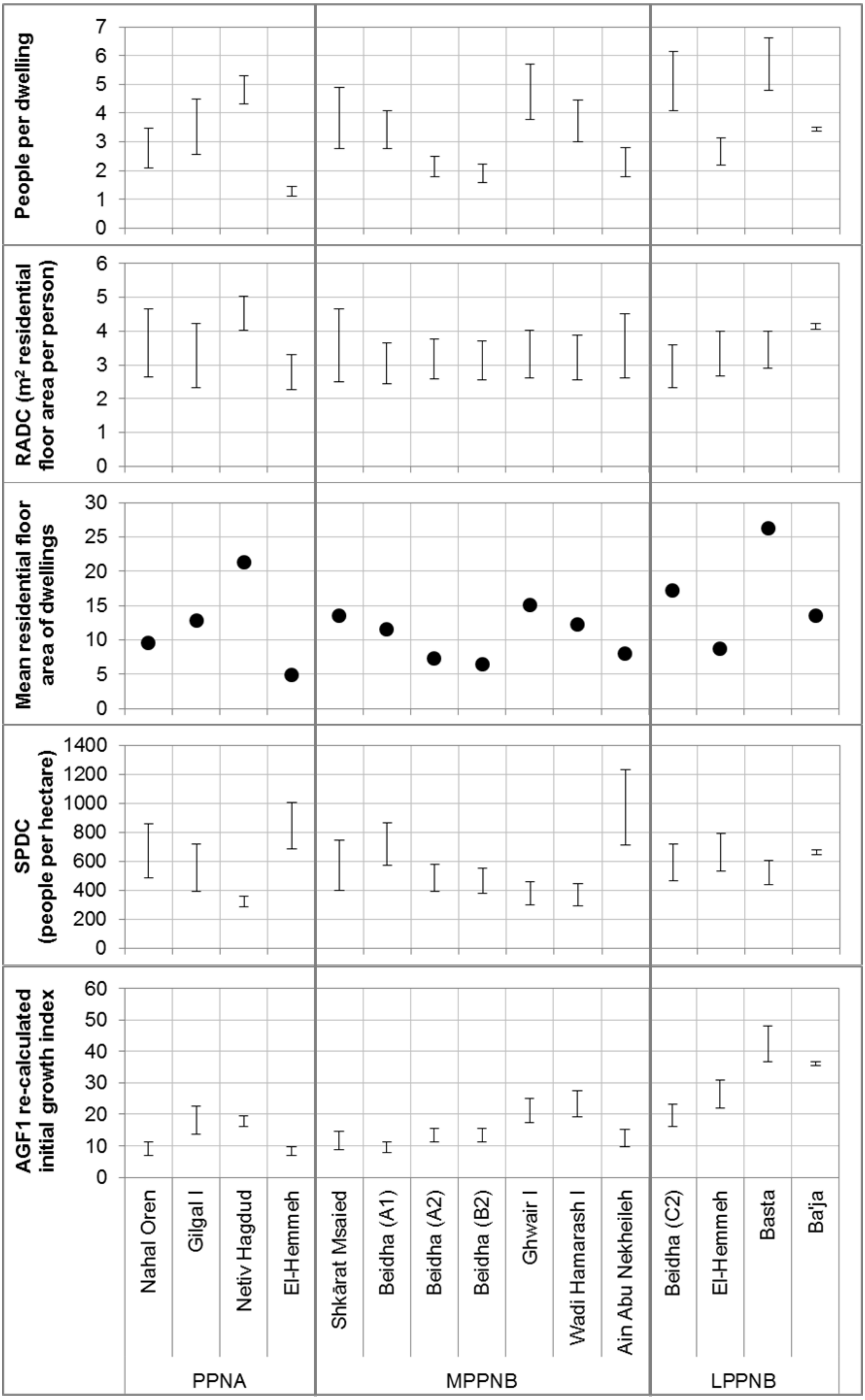


Figure 7.38. Summary of micro-level estimates.

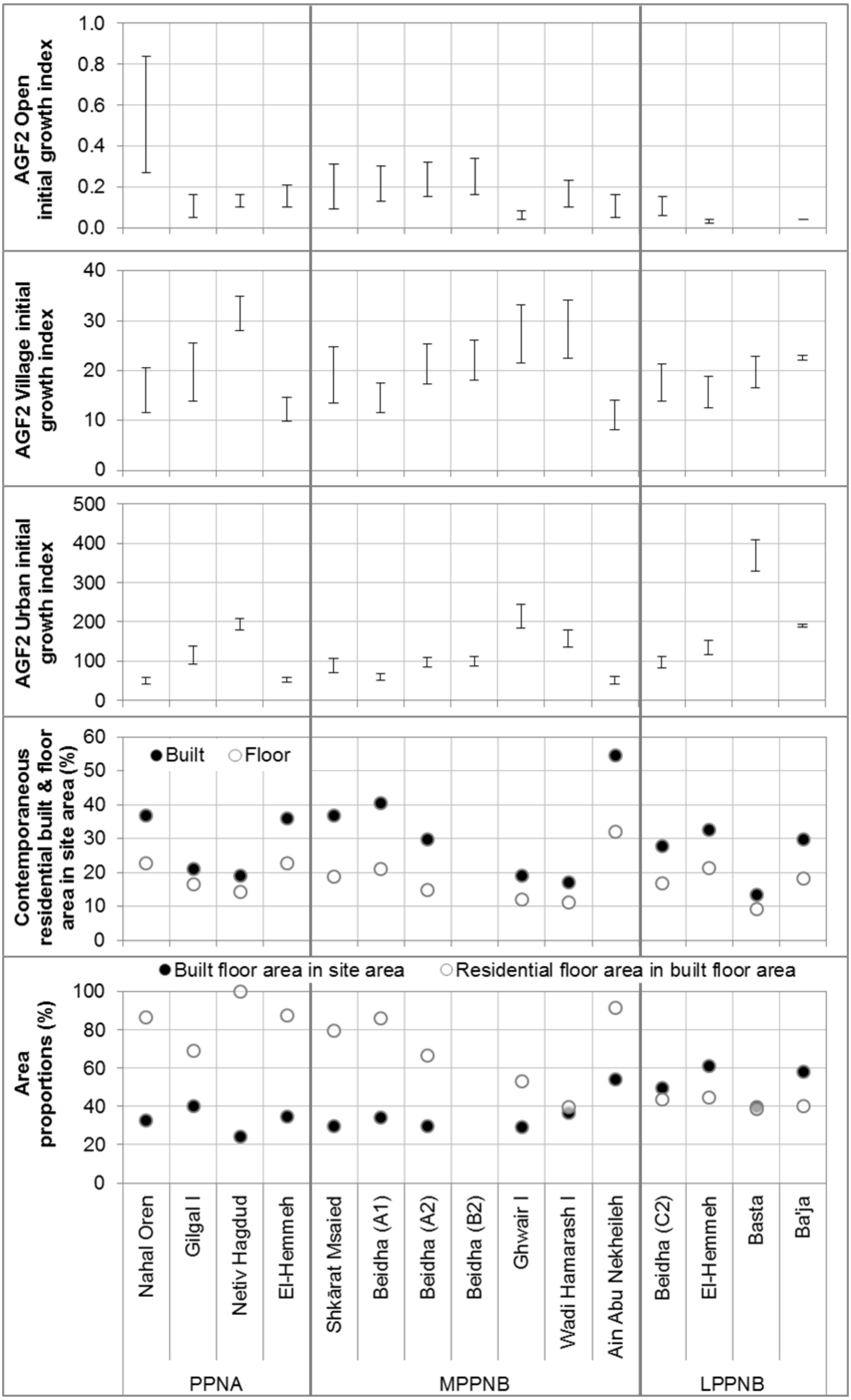


Figure 7.38. Summary of micro-level estimates (continued).

7.3 Summary

Methodologies for estimating population parameters have been applied to 11 PPN central and southern Levantine villages across 15 phases. This included Bayesian chronological modelling of several sites, which further highlighted the potential of this method for producing phase length and building use-life estimates for reconstructing structural contemporaneity values.

Estimates of population parameters based on the SPF were assessed. Cross-analyses of estimates with archaeological evidence support several hypothesised group size thresholds, particularly relating to initial sedentism ($P \geq 25$) (Fletcher 1981; Binford 2001; Kuijt and Goring-Morris 2002; Bandy 2010); the adoption of farming practices ($P \geq 50$) (Drennan and Peterson 2008) and a fully agro-pastoralist subsistence strategy ($P = 100\text{-}750$) (Fletcher 1981; Kuijt and Goring-Morris 2002). The majority of sites contained evidence for the introduction of mechanisms to reduce scalar stress ($P \geq 150$) (Chagnon 1980; Kosse 1990; Bowser 2000; Kuijt and Goring-Morris 2002; Dunbar 2003; Bandy 2006; Alberti 2014); and for the transition from a more egalitarian to more complex social structure ($P \geq 350$) (Forge 1972; Kosse 1990), including individuals with authoritative roles ($P \geq 500$) (Naroll 1956; Kosse 1990). Finally, some sites (i.e. LPPNB el-Hemmeh, Ba'ja and Basta) demonstrate evidence for innovative farming methods (expected to occur at $P \geq 3{,}000$) (Bogaard and Isaakidou 2010).

In some cases, these developments are not present within sites whose population estimates exceed these thresholds (i.e. pastoral practices do not occur in the earliest PPN sites regardless of population size). Conversely, some developments appear to occur at lower population sizes. The presence of more advanced processes at lower population thresholds may reflect the broader social networks that occurred at this time (i.e. Nahal Oren and additional sites on Mount Carmel; Gilgal I, Netiv Hagdud and additional sites in the Salibiya Basin; Shkārat Msaied and nearby Beidha). Networks extending as far as the northern Levant would have enabled transmission of ideas, products and people from potentially more developed regions. These networks would have effectively formed a larger overall population. The resulting population pressure on resources and social stress within these communities may have led to innovative methods for improving resource availability and reducing scalar stress (Coward and Dunbar 2014). Therefore, an analysis of the combined population sizes of settlement networks may be a more effective means of exploring settlement and population parameters.

Dwelling unit size estimates were assessed to determine the potential for nuclear family dwelling units, which are often considered to represent the predominant dwelling unit type of PPN settlements (Sweet 1960; Wright 1969; Antoun 1972; Watson 1978;

1979; Kramer 1979; 1982; Aurenche 1981; van Beek 1982; Finkelstein 1990; Zorn 1994). Estimates ranged from around one to 6.5 people per dwelling. Several sites (PPNA el-Hemmeh; MMPNB Beidha Subphases A2 and B2; MPPNB 'Ain Abu Nekheileh) recorded dwelling unit size estimates lower than that of the minimum nuclear family size (3 people), indicating that nuclear families may not have typified the dwelling unit in these settlements. All other sites produced estimates that could indicate nuclear family dwelling units. However, as the SPF are based on average adult human heights, depending on the stature of individuals or the presence of children, dwelling unit sizes could be larger than those estimated in this analysis.

Estimates of residential floor area per person (RADC) ranged from around 2.3 m^2 to five m^2. These compare well with RADCs derived in other analyses (2.16-4.55 m^2 per person) (Hill 1970; Clarke 1974; Kramer 1979; Hayden *et al.* 1996). The limited range suggests that RADCs could be used to estimate population from total residential floor area in future.

Settlement population density coefficient (SDPC) estimates ranged from around 290 to 1,230 people. Almost all SPDC estimates exceed the density coefficients commonly utilised for estimating PPN Levantine village populations (90-294 people/ha) (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009), with some also exceeding the upper density limit suggested for early agricultural villages (1,000 people/ha) (Fletcher 1981). Consideration of children in the SPF estimates would further increase density values derived in this investigation.

Initial growth indices (*a*) for the AGF1 (Naroll 1962) and AGF2 (Wiessner 1974) were reconstructed to determine whether patterns exist between different types of settlements. There was a clear distinction between the AGF1 index ranges for settlements with predominantly curvilinear architecture (mean *a* = 10.3-15.1) and those with predominantly rectilinear architecture (mean *a* = 24.5-31.9). The mean AGF1 index achieved in this investigation (18.9) is closely comparable to Naroll's (1962) original index (21.7). These results indicate that type-based AGF1 initial growth indices could be used to estimate population in future.

Considerable differences occurred between the AGF2 open and urban indices for sites conforming to these settlement types and those that did not. The open settlement recorded an index of 0.27 to 0.84. The urban settlement recorded an index of 329 to 408. However, as there is only one site potentially corresponding to each of these settlement types, the open and urban indices could not be refined and are not explored further in this analysis. The AGF2 village indices demonstrate considerable overlap regardless of settlement type (mean *a* = 16.1-23.8). This raises the possibility of a universal AGF2 village index for estimating the population of any central and southern Levantine PPN village.

Area proportions were mainly derived to create constants for systematic methodologies. Of particular interest are the estimates of the proportion of residential floor area in built floor area. Lower proportions were recorded in sites with predominantly rectilinear architecture and those that occur later in the PPN sequence. This reflects the increased designation of space for non-residential activities within these settlements.

The results of micro-level analyses are statistically assessed in the following chapter to develop a site type classification system for PPN central and southern Levantine villages and to construct constants for several variables utilised in methodologies for systematically estimating population parameters based on site size and an assigned site type.

8 Micro-Level Estimates – Statistical Analysis

Statistical analysis was conducted to (1) establish an appropriate site type classification system for central and southern Levantine PPN villages; and (2) to provide justification for the development of either site type or universal constants for the 14 variables utilised in the systematic methodologies. These variables include people per dwelling; residential floor area and settlement population density coefficients (RADC and SPDC); the four initial growth indices (AGF1 re-calculated and AGF2 open, village and urban); the mean residential floor area and residential built area of complete dwellings; proportions of built floor area, contemporaneous residential built area and contemporaneous residential floor area in assessable area; the proportion of residential floor area in built floor area; and the number of contemporaneous dwellings per hectare (Table 7.36). Statistical methods explore the correlation between the 14 variables, site size and predominant architectural form to develop the classification system and constants that are essential for producing an empirically and statistically robust, standardised methodology.

Three main statistical methods are explored. Discriminant function analysis (DFA) is used to determine the most appropriate site type classification system. To provide justification for the development of constants, analysis of variance (ANOVA) and the Kruskal-Wallis tests are used to determine whether significant differences exist in the mean and median values of variables between site types; and analysis of effect size (ETA squared/eta^2) is used to determine the percentage of variation between the values of variables that is attributable to differences in site type. Process charts for statistical methods and information regarding interpretation of statistical outputs are provided in Appendix D.

8.1 Hypothesised site type classification systems

In order to extrapolate micro-level data for use in systematic methods, a standardised site type classification system is required. Based on the 15 villages/village phases assessed at the micro-level, two relatively easily discernible characteristics were selected to establish potential site types: predominant architectural form (curvilinear or rectilinear) and a site size category (small, large or very large). Site size categories differ marginally for sites of different architectural form. This reflects the generally smaller sizes of sites with curvilinear architecture and allows for more than one case per site type, which is essential for statistical analysis. Five potential site type classification systems are proposed:

1. A five type system based on site size and predominant architectural form:
   - 1: small (< 0.4 ha) and 2: large (≥ 0.4 ha) sites with predominantly curvilinear architecture
   - 3: small (≤ 0.5 ha), 4: large (0.6-6 ha) and 5: very large [“mega”] (≥ 7 ha) sites with predominantly rectilinear architecture.

2. A four type system based on site size and predominant architectural form:
   - 1: small (< 0.4 ha) and 2: large (≥ 0.4 ha) sites with predominantly curvilinear architecture
   - 3: small (≤ 0.5 ha) and 4: large (≥ 0.6 ha) sites with predominantly rectilinear architecture.

3. A three type system based on site size:
   - 1: small sites (< 0.4 ha: curvilinear; ≤ 0.5 ha: rectilinear)
   - 2: large sites (≥ 0.4 ha: curvilinear; 0.6-6 ha: rectilinear)
   - 3: very large [“mega”] sites (≥ 7 ha)

4. A two type system based on site size:
   - 1: small sites (< 0.4 ha: curvilinear; ≤ 0.5 ha: rectilinear)
   - 2: large sites (≥ 0.4 ha: curvilinear; ≥ 0.6 ha: rectilinear).

5. A two type system based on predominant architectural form:
   - 1: sites with predominantly curvilinear architecture
   - 2: sites with predominantly rectilinear architecture.

Micro-level analysis did not include any sites with an estimated areal extent of between two and 10 hectares. The cut-off point between large (0.6-6 ha) and very large sites (≥ 7 ha) with rectilinear architecture was based on the minimum site size generally applied to “mega-sites”, which have been estimated at anywhere between seven and 16 hectares (Rollefson 1989a).

8.2 Methodological issues and considerations

Statistical analyses are most effective when there are a large number of cases ($n > 30$). Unfortunately, there are only 15 cases (i.e. villages/village phases) in this analysis, which slightly reduces the reliability of significance values. When cases are split into different site type categories, the number of cases per category varies from one to 10. Some statistical tests, such as post-hoc tests for analysis of variance (ANOVA), omit categories with less than two cases (i.e. site types relating to ‘very large’ sites only have one case: Basta), reducing the informativeness of the results. Despite the small sample size in this investigation and the potential for reduced reliability of significance values, statistical analysis remains an important tool for identifying trends in the data.

8.3 Tests for normality and homogeneity of variance

Ideally, data submitted to the chosen tests should be parametric: that is, data should be normally distributed and have homogeneity of variance. To determine whether data are parametric, data were submitted to a one sample Kolmogorov-Smirnov test to assess for normal distribution and to Levene’s test to assess for homogeneity of variance (see Appendix D). Prior to the tests, variables recorded as proportions were arcsine transformed (i.e. converted to the arc sine value of the square root of the proportion) as statistical analysis of proportion values is problematic (McDonald 2014).

In the one sample Kolmogorov-Smirnov test, a significance value (*p*) of greater than .05 indicates normal distribution. The test indicated that all variables were normally distributed (Table 8.1).

Levene’s tests were achieved via analysis of variance (ANOVA) tests. A significance value (*p*) of greater than .05 indicates homogeneity of variance (i.e. that the variance within each of the variables is equal). ANOVA requires a grouping variable. In this analysis, the grouping variable is the site type classification system. For site type systems involving five and three types, ANOVA omitted the site types relating to the ‘very large’ site (Basta) as this type has fewer than two cases. Of the 14 variables assessed, three were identified as lacking homogeneity of variance in one or more of the site type classification systems (RADC; the AGF1 re-calculated initial growth index; and the proportion of residential floor area in built floor area (Table 8.2). This somewhat reduces the reliability of the significance values in further tests.

Tests for normality and homogeneity of variance indicated that most variables (n = 11/14) were parametric. The remaining variables are normally distributed though lack homogeneity of variance. The chosen tests are considered robust despite incorporation of non-parametric data, particularly where divergence from normality or homogeneity is minimal (Drennan 1996; Tabachnick and Fidell 1996; Underwood 1997). Therefore, the potential non-parametric nature of this data is not expected to impact statistical analyses in any significant way.

Table 8.1. One-sample Kolmogorov-Smirnov test for normality.

					Initial growth index				Mean residential area of complete dwellings (m^2)		Proportion in site area (arcsine):				
												Contemporaneous residential area			
		People/dwelling	**RADC (m^2 residential floor area/person)**	**SPDC (people/ha)**	*AGF1 re-calculated*	*AGF2 open*	*AGF2 village*	*AGF2 urban*	*Floor*	*Built*	*Built floor area*	*Built*	*Floor*	**Proportion of residential floor area in built floor area (arcsine)**	**Contemporaneous dwellings per hectare**
N		15	15	15	15	15	15	15	15	15	14	14	14	14	15
Normal parameters	Mean	3.38	3.44	575.68	18.98	.169	20.08	131.88	12.55	20.47	.69	.58	.44	.99	173.56
	SD	1.29	.45	166.44	9.84	.14	5.75	84.51	5.77	7.73	.13	.11	.07	.27	98.41
Most extreme differences	Absolute	.128	.184	.105	.181	.187	.128	.185	.169	.170	.190	.111	.136	.159	.151
	Positive	.128	.184	.105	.181	.187	.128	.185	.169	.170	.190	.111	.136	.159	.151
	Negative	-.119	-.110	-.064	-.149	-.123	-.099	-.170	-.090	-.086	-.143	-.085	-.077	-.122	-.140
Kolmogorov-Smirnov Z		.498	.711	.408	.702	.724	.497	.716	.656	.658	.711	.416	.510	.595	.585
Asymp. sig. (2-tailed) (*p*)*		.965	.693	.996	.707	.671	.966	.684	.783	.779	.692	.995	.957	.870	.884

* $p > .05$ indicates normal distribution.

Table 8.2. Levene's statistic for homogeneity of variance (variables lacking homogeneity of variance highlighted in grey).

Classification system	Statistics	People/dwelling	RADC (m^2 residential floor area/person)	SPDC (people/ha)	Initial growth index: *AGF1 re-calculated*	Initial growth index: *AGF2 open*	Initial growth index: *AGF2 village*	Initial growth index: *AGF2 urban*	Mean residential area of complete dwellings (m^2): *Floor*	Mean residential area of complete dwellings (m^2): *Built*	Proportion in site area (arcsine): *Built floor area*	Proportion in site area (arcsine): *Contemporaneous residential area*: *Built*	Proportion in site area (arcsine): *Contemporaneous residential area*: *Floor*	Proportion of residential floor area in built floor area (arcsine)	Contemporaneous dwellings per hectare
5 Site Types[a]	Levene	.026	6.79	.17	4.737	.902	.85	2.997	1.115	.276	1.297	.645	.388	12.976	.450
	df1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	df2	10	10	10	10	10	10	10	10	10	9	9	9	9	10
	Sig. (*p*) [b]	.994	.009	.91	.026	.474	.49	.082	.388	.841	.334	.605	.764	.001	.723
4 Site Types	Levene	.850	4.53	.26	11.53	.974	.98	2.400	1.181	.240	.488	.624	.354	14.809	.453
	df1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	df2	11	11	11	11	11	11	11	11	11	10	10	10	10	11
	Sig. (*p*)	.495	.027	.84	.001	.440	.43	.123	.362	.867	.698	.616	.787	.001	.720
3 Site Types[a]	Levene	.391	5.33	.05	1.414	1.00	.16	.795	.000	.301	3.968	.245	.894	.488	.585
	df1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	df2	12	12	12	12	12	12	12	12	12	11	11	11	11	12
	Sig. (*p*)	.543	.040	.82	.257	.335	.69	.390	.984	.593	.072	.631	.365	.499	.459
2 Site Types (size)	Levene	.000	2.55	.43	4.899	1.09	.03	2.160	1.923	.014	4.447	.631	1.464	.163	.934
	df1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	df2	13	13	13	13	13	13	13	13	13	12	12	12	12	13
	Sig. (*p*)	1.00	.134	.52	.045	.315	.85	.165	.189	.908	.057	.442	.250	.693	.352
2 Site Types (architecture)	Levene	.056	.598	.85	8.348	.845	.03	1.847	.058	.041	1.368	1.058	.289	1.868	1.454
	df1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	df2	13	13	13	13	13	13	13	13	13	12	12	12	12	13
	Sig. (*p*)	.816	.453	.37	.013	.375	.86	.197	.814	.842	.265	.324	.601	.197	.249

[a] One type removed as it contains only one case.
[b] $p > .05$ indicates homogeneity of variance.

8.4 Discriminant function analysis

Discriminant function analysis (DFA) was conducted in SPSS to determine the most appropriate classification system for PPN central and southern Levantine villages (see Appendix D). DFA reveals whether cases (i.e. sites) are correctly classified by predicting categorical groupings based on linear sets of non-related predictor or discriminating variables, called discriminating functions (Adams 1988, p.50; Huberty and Olejnik 2006; Kovarovic *et al.* 2011, p.3008).

There is no clear consensus as to the required ratio between the number of cases and the number of discriminant variables. Kovarovic *et al.* (2011, p.3008) suggest that the number of discriminant variables should not exceed the sample size of the smallest group. In this study, the sample size of the smallest group is one (potential *n* variables = 1). Alternatively, they propose on a mathematical basis that the number of variables should be less than or equal to the number of cases in the entire sample minus the number of groups. In this study, the number of cases (i.e. sites) in the entire same is 15 and the number of groups (i.e. site types) ranges from two to five (potential *n* variables = 10-13). Others propose that the total number of cases must be a multiple (i.e. 3-5 times) of the number of discriminant variables (Burns and Burns 2008, p.591) (potential *n* variables = 3-5). In this investigation, five discriminant variables were selected for analysis. These variables were selected based on (1) their potential to further our understanding of demographic processes within early PPN villages; (2) their ability to distinguish between settlement types; and (3) their usefulness for estimating population size in future. The discriminant variables include people per dwelling, RADC, SPDC and initial growth indices for AGF1 re-calculated and AGF2 village. For each of the site type classification systems, one of these variables was identified as containing non-parametric data. Five types: small (1) or large (2) with curvilinear architecture; small (3), large (4) or very large (5) with rectilinear architecture

DFA of the five type classification system indicated that discriminant Function 1 explained 93.6% of the variance between site types (Eigenvalue: 21.927; r = .978), with Function 2 explaining a further 2.9% (Eigenvalue: .671; r = .634) (Table 8.3; Figure 8.1). Functions 1 and 2 combined explained 96.4% of the variance between site types. The importance of Function 1 within the classification system is highlighted by the Wilks' Lambda results, which indicate that combinations that do not include Function 1 do not contribute significance ($p < .05$) to the classification system.

The largest correlation between variables and functions is recorded in the structure matrix. Variables with a correlation of 0.3/-0.3 or more are considered important within that function. Factor loading of important variables within Function 1 and, to a lesser degree, Function 2 indicate that the best predictor for classifying sites is the AGF1 re-calculated initial growth index (Function 1: .607; Function 2: -.397). This supports the development of site type constants for this variable.

The final classification results table indicates that 93.3% of cases were classified correctly within the five type system. Casewise statistics indicates that all original groupings (actual groups) coincide with predicted groups, except case 12 (Ghwair I), which was re-classified from a Type 4 (large: 0.6-6 ha with rectilinear architecture) to Type 3 (small: ≤ 0.5 ha with rectilinear architecture) site. The architecture and spatial layout of Ghwair I may demonstrate more similarities with Type 3 sites (Wadi Hamarash I and Beidha Subphase C2) than Type 4 sites (LPPNB el-Hemmeh and Ba'ja). However, due to the comparability of site sizes of Type 4 sites assessed at the micro-level in this investigation, and the designated site size categories used in the classification system, re-classification was not possible. Further, the close proximity of the Type 3 and Type 4 group centroids (Figure 8.1) indicates that there may be considerable overlap in characteristics of these site types. As such, re-classification was not deemed necessary.

8.4.1 Four types: small (1) or large (2) with curvilinear architecture; small (3) or large (4) with rectilinear architecture

Three discriminant functions were utilised in the analysis of the four type classification system based on site size and predominant architectural form. Function 1 (Eigenvalue: 4.893; r = .911) explains 81.8% of the variance (Table 8.4; Figure 8.2). Functions 1 and 2 combined explain 92.2% of the variance. The Wilks' Lambda test indicates that the combination of functions that includes Function 1 (i.e. 'Test of Functions 1 through 3') contributes significantly to the classification system (Wilks' Lambda .071; χ^2 = 25.103, df = 15, p = .049). Factor loading of variables within Functions 1 and 2 indicate that the re-calculated AGF1 initial growth index is the best predictor for classifying sites (Function 1: .827; Function 2: -.440), followed by people per dwelling (Function 1: .399) and RADC (Function 2: -.821).

DFA indicated that 86.7% of cases were correctly classified, highlighting two misclassified cases (8: Gilgal I - re-classified from a Type 2 (large) to Type 1 (small) site with curvilinear architecture; 12: Ghwair I – re-classified from a Type 4 (large) to Type 3 (small) site with rectilinear architecture). Based on the increased incidence of misclassified cases compared to the five type classification system, the four type classification system is considered less suitable for classifying PPN villages.

8.4.2 Three types: small (1), large (2) or very large (3)

Two discriminant functions were utilised in the analysis of the three type classification system based on site size (small, large or very large) (Table 8.5; Figure 8.3). Function 1 (Eigenvalue: 3.735; *r* = .888) explains 89.7% of the variance. The Wilks' Lambda test indicates that the combination of functions that includes Function 1 (i.e. 'Test of Functions 1 through 2') contributes significantly to the classification system (Wilks' Lambda .148; χ^2 = 19.122, *df* = 10, *p* = .039). Factor loading of variables again indicated that the re-calculated AGF1 initial growth index is the best predictor for classifying sites (Function 1: -.768), followed by people per dwelling (Function 1: -.389) and RADC (Function 2: .706).

DFA indicated that 86.7% of cases were correctly classified, identifying two misclassified cases (8: Gilgal I and 12: Ghwair I - both re-classified from a Type 2 (large) to Type 1 (small) site). Based on the increased incidence of misclassified cases compared to the five type classification system, the three type classification system is considered less suitable for classifying PPN villages..

8.4.3 Two types (size): small (1) or large (2)

One discriminant function (Eigenvalue: 1.462; *r* = .771) was utilised in the analysis of the two type classification system based on site size (small or large) (Table 8.6). The Wilks' Lambda test indicated that this function does not contribute significantly to the classification system (Wilks' Lambda .406; χ^2 = 9.458, *df* = 5, *p* = .092). Factor loading of variables again indicated that the re-calculated AGF1 initial growth index is the best predictor for classifying sites (.803).

DFA indicated that 86.7% of cases were correctly classified, highlighting two misclassified cases (8: Gilgal I and 12: Ghwair I - both re-classified from a Type 2 (large) to Type 1 (small) site). Based on the lack of significant contribution of functions to the classification system and the increased incidence of misclassified cases compared to the five type classification system, the two type classification system based on site size is considered less suitable for classifying PPN villages.

8.4.4 Two types (architecture): curvilinear (1) or rectilinear (2)

One discriminant function was utilised in the analysis of the two type classification system based on predominant architectural form (curvilinear or rectilinear) (Eigenvalue: 3.712; r = .888) (Table 8.7). This function contributes significantly to the classification system (Wilks' Lambda .212; χ^2 =16.275, df = 5, p = .006). Factor loading of variables indicated that the re-calculated AGF1 initial growth index is the best predictor for classifying sites (.670), followed by people per dwelling (.345).

DFA identified that 100% of sites were correctly classified, indicating that architectural form contributes significantly to the classification system. However, this system was considered too simple and, therefore, it was decided that the five type classification system, which had a high percentage of correctly classified sites (93.3%), would be utilised to classify PPN central and southern Levantine villages.

8.4.5 Final selection of classification system

DFA indicated that 93.3% (all but one) of cases within the five type system were classified correctly (case 12: Ghwair I was re-classified from a large to small site). For classification systems involving four and three site types, and two site types based on site size, DFA indicated two incorrectly classified cases (cases 8: Gilgal I and 12: Ghwair I) (86.7% correctly classified). For the two site type system based on architectural form, DFA identified all cases as being correctly classified. This suggests that architectural form contributes more significantly than site size to the classification system. However, the two type classification system is considered too broad to reflect differences that occur within settlements of the same architectural form. Therefore, it was decided that the five type system, which had a high percentage (93.3%) of correctly classified cases, would be more effective for classifying PPN central and southern Levantine villages. The remaining statistical analyses in this investigation are applied to variables based on the five type classification system (Table 8.8; Figure 8.4).

Table 8.3. Discriminant function analysis - five site type classification system.

Eigenvalues

Function	Eigenvalue	% of	Cumulative %	Canonical Correlation
1	21.927	93.6	93.6	.978
2	.671	2.9	96.4	.634
3	.521	2.2	98.7	.585
4	.313	1.3	100.0	.488

Wilks' Lambda

Test of Function(s)	Wilks'	Chi-square	df	Sig. (*p*)
1 through 4	.013	39.036	20	.007
2 through 4	.300	10.845	12	.542
3 through 4	.501	6.224	6	.399
4	.762	2.451	2	.294

p < .05 = significant contribution

Structure Matrix

	Function			
	1	2	3	4
AGF2 village index	.078	.126	0.885*	.010
SPDC (people/ha)	-.076	-.101	-.681*	.310
RADC (m^2 residential floor area/person)	.024	-.589	.662*	.238
AGF1 re-calculated index	.607	-.397	.088	.680*
People/dwelling	.252	.103	.551	-.651*

* Largest absolute correlation between each variable and any discriminant function

Casewise Statistics

Case Number	Site Name	Actual Group	Highest Group: Predicted Group	P(D>d | G=g) p	df	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid
1	Nahal Oren	1	1	.393	4	1.000	4.100
2	El-Hemmeh (PPNA)	1	1	.331	4	1.000	4.602
3	Shkārat Msaied	1	1	.568	4	.915	2.937
4	Beidha (A1)	1	1	.594	4	.992	2.787
5	Beidha (A2)	1	1	.972	4	.988	.519
6	Beidha (B2)	1	1	.982	4	.993	.405
7	‘Ain Abu Nekheileh	1	1	.826	4	1.000	1.502
8	Gilgal I	2	2	.609	4	.887	2.702
9	Netiv Hagdud	2	2	.609	4	.994	2.702
10	Wadi Hamarash I	3	3	.783	4	.697	1.745
11	Beidha (C2)	3	3	.783	4	.920	1.745
12	Ghwair I	4	3	.914	4	.861	.975
13	El-Hemmeh (LPPNB)	4	4	.422	4	.968	3.880
14	Ba'ja	4	4	.297	4	.997	4.910
15	Basta	5	5	1.000	4	1.000	.000

Classification Results[b]

	Site Type	Predicted Group Membership: 1	2	3	4	5	Total
Count	1	7	0	0	0	0	7
	2	0	2	0	0	0	2
	3	0	0	2	0	0	2
	4	0	0	1	2	0	3
	5	0	0	0	0	1	1
%	1	100.0	.0	.0	.0	.0	100.0
	2	.0	100.0	.0	.0	.0	100.0
	3	.0	.0	100.	.0	.0	100.0
	4	.0	.0	33.3	66.7	.0	100.0
	5	.0	.0	.0	.0	100.0	100.0

[a] Misclassified case.
[b] 93.3% of original grouped cases correctly classified.

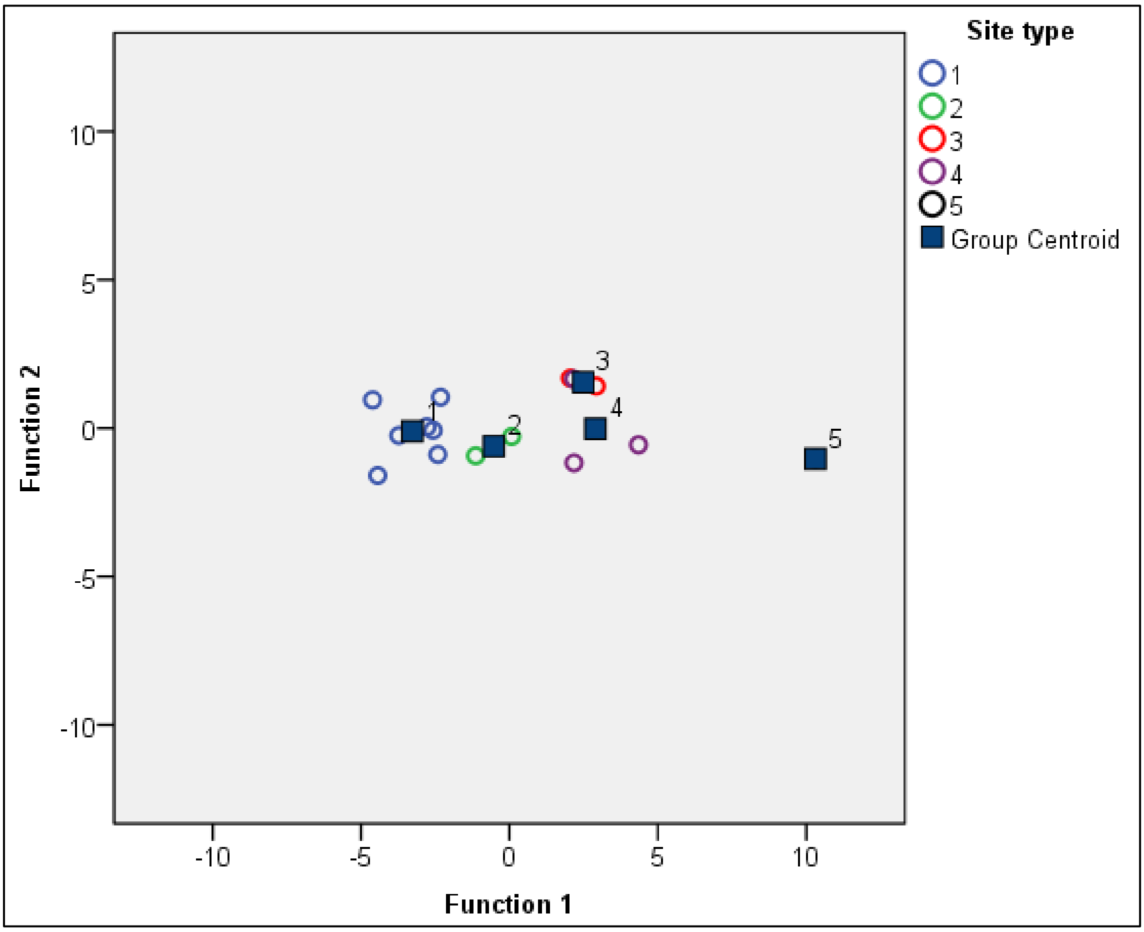


Figure 8.1. Discriminant function analysis - five site type classification system: distance to group centroid based on discriminant functions 1 and 2.

Table 8.4. Discriminant function analysis - four site type classification system.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	4.893	81.8	81.8	.911
2	.625	10.4	92.2	.620
3	.467	7.8	100.0	.564

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig. (*p*)
1 through 3	.071	25.103	15	.049
2 through 3	.419	8.254	8	.409
3	.682	3.642	3	.303

$p < .05$ = significant contribution

Structure Matrix

	Function		
	1	2	3
AGF1 re-calculated index	.827*	-.440	-.328
RADC (m^2 residential floor area/person)	.062	-.821*	.314
AGF2 village index	.214	-.212	.776*
SPDC (people/ha)	-.169	.111	.730*
People/dwelling	.399	-.037	.612*

* Largest absolute correlation between each variable and any discriminant function

Casewise Statistics

Case Number	Site Name	Actual Group	Highest Group: Predicted Group	P(D>d | G=g) p	df	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid
1	Nahal Oren	1	1	.339	3	.985	3.364
2	El-Hemmeh (PPNA)	1	1	.502	3	.999	2.357
3	Shkārat Msaied	1	1	.680	3	.878	1.510
4	Beidha (A1)	1	1	.546	3	.980	2.131
5	Beidha (A2)	1	1	.974	3	.960	.220
6	Beidha (B2)	1	1	.972	3	.962	.234
7	‘Ain Abu Nekheileh	1	1	.863	3	.993	.744
8	Gilgal I	2	1[a]	.461	3	.707	2.582
9	Netiv Hagdud	2	2	.515	3	.988	2.285
10	Wadi Hamarash I	3	3	.958	3	.759	.312
11	Beidha (C2)	3	3	.958	3	.934	.312
12	Ghwair I	4	3[a]	.869	3	.890	.719
13	El-Hemmeh (LPPNB)	4	4	.174	3	.717	4.965
14	Ba'ja	4	4	.691	3	.998	1.460
15	Basta	4	4	.242	3	.998	4.191

Classification Results[b]

	Site Type	Predicted Group Membership 1	2	3	4	Total
Count	1	7	0	0	0	7
	2	1	1	0	0	2
	3	0	0	2	0	2
	4	0	0	1	3	4
%	1	100.0	.0	.0	.0	100.0
	2	50.0	50.0	.0	.0	100.0
	3	.0	.0	100.0	.0	100.0
	4	.0	.0	25.0	75.0	100.0

[a] Misclassified case.
[b] 86.7% of original grouped cases correctly classified.

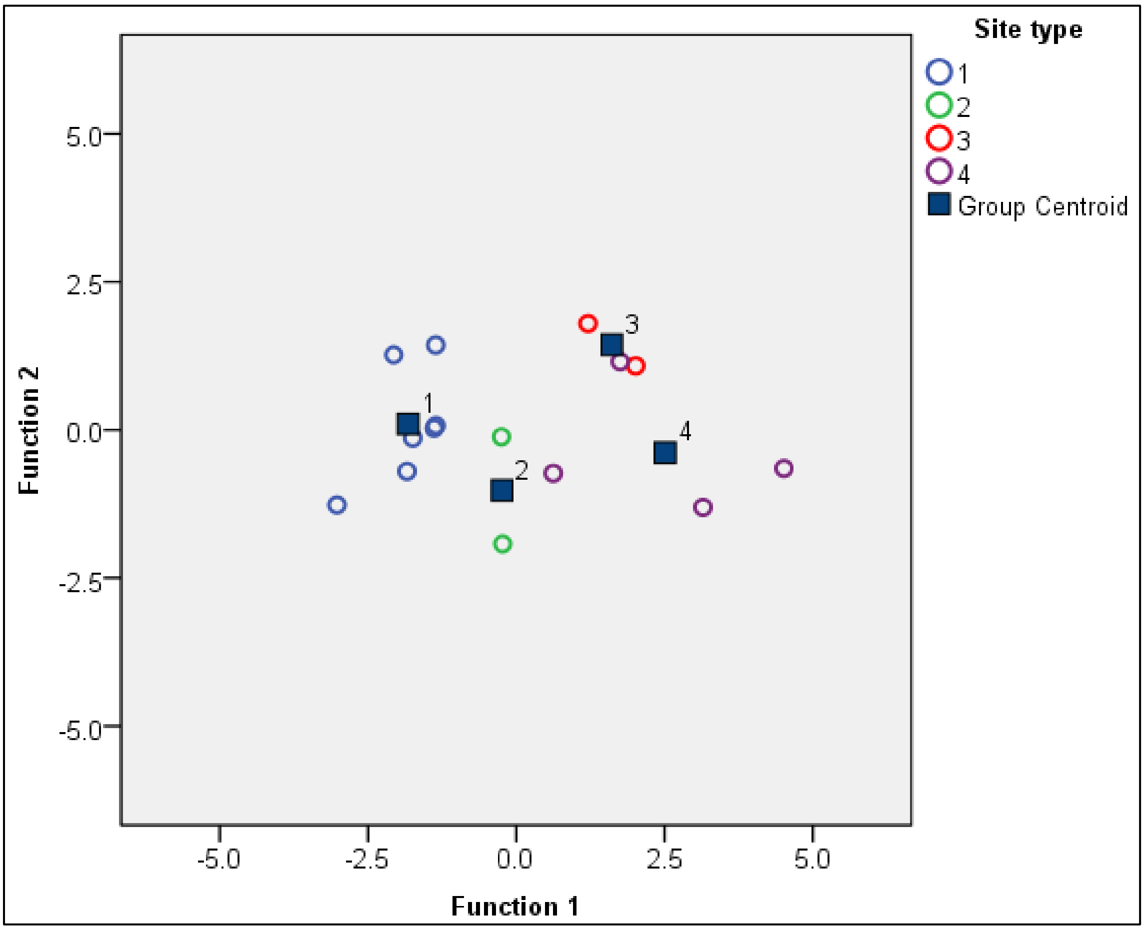


Figure 8.2. Discriminant function analysis - four site type classification system.

Table 8.5. Discriminant function analysis - three site type classification system.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.735	89.7	89.7	.888
2	.430	10.3	100.0	.548

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig. (*p*)
1 through 2	.148	19.122	10	.039
2	.700	3.573	4	.467

p < .05 = significant contribution

Structure Matrix

	Function 1	Function 2
AGF1 re-calculated index	-.768*	.245
People/dwelling	-.389*	.050
RADC (m^2 residential floor area/person)	-.173	.706*
AGF2 village index	-.123	.648*
SPDC (people/ha)	.130	-.340

* Largest absolute correlation between each variable and any discriminant function

Casewise Statistics

Case Number	Site Name	Actual Group	Highest Group: Predicted Group	Highest Group: P(D>d | G=g) p	Highest Group: P(D>d | G=g) df	Highest Group: P(G=g | D=d)	Highest Group: Squared Mahalanobis Distance to Centroid
1	Nahal Oren	1	1	.967	2	.930	.067
2	El-Hemmeh (PPNA)	1	1	.182	2	.999	3.403
3	Shkārat Msaied	1	1	.761	2	.840	.546
4	Beidha (A1)	1	1	.570	2	.995	1.126
5	Beidha (A2)	1	1	.979	2	.951	.043
6	Beidha (B2)	1	1	.903	2	.959	.204
7	‘Ain Abu Nekheileh	1	1	.765	2	.976	.536
8	Gilgal I	2	1[a]	.394	2	.624	1.865
9	Netiv Hagdud	2	2	.234	2	.921	2.905
10	Wadi Hamarash I	1	1	.318	2	.535	2.289
11	Beidha (C2)	1	1	.140	2	.800	3.926
12	Ghwair I	2	1[a]	.421	2	.558	1.728
13	El-Hemmeh (LPPNB)	2	2	.225	2	.885	2.979
14	Ba'ja	2	2	.196	2	.997	3.255
15	Basta	3	3	1.000	2	1.000	.000

Classification Results[b]

	Site Type	Predicted Group Membership 1	2	3	Total
Count	1	9	0	0	9
	2	2	3	0	5
	3	0	0	1	1
%	1	100.0	.0	.0	100.0
	2	40.0	60.0	.0	100.0
	3	.0	.0	100.0	100.0

[a] Misclassified case.
[b] 86.7% of original grouped cases correctly classified.

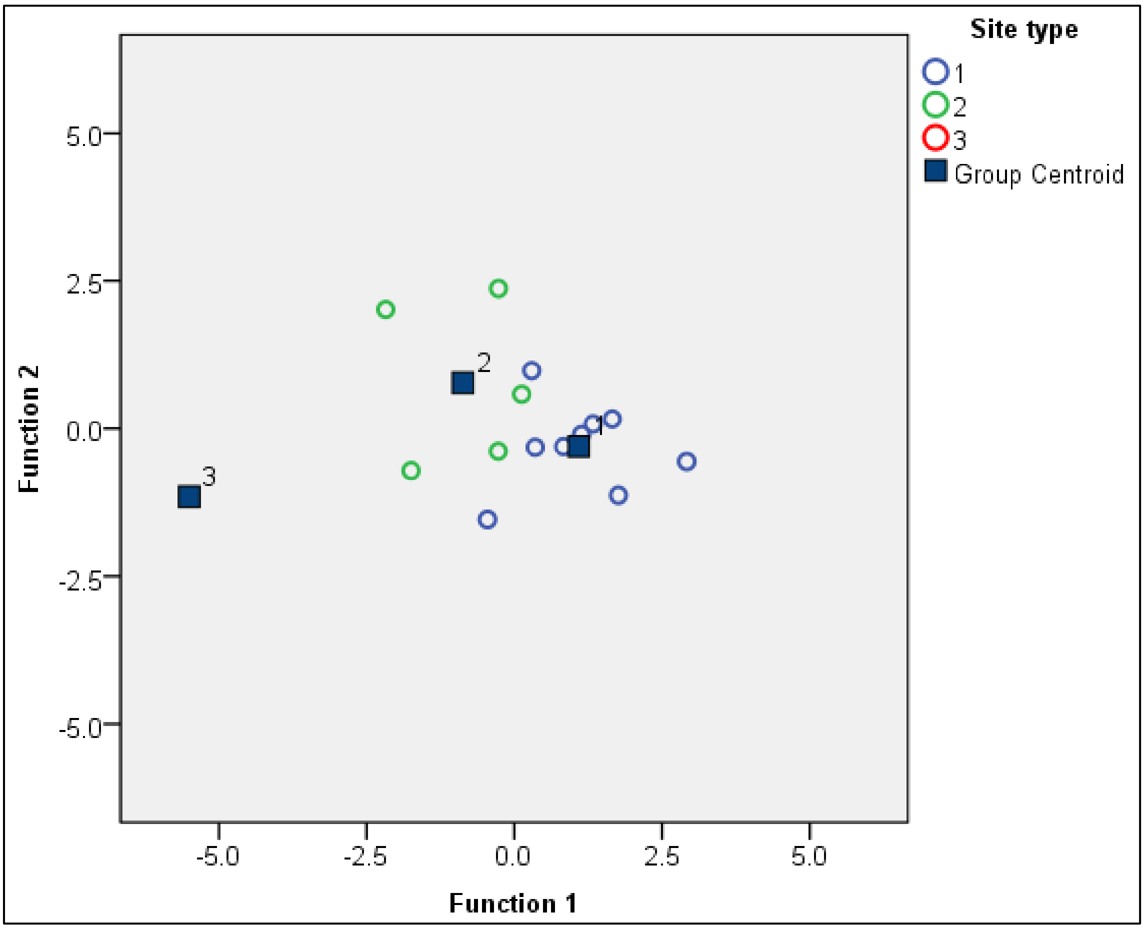


Figure 8.3. Discriminant function analysis - three site type classification system.

Table 8.6. Discriminant function analysis - two site type classification system (size).

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.462	100.0	100.0	.771

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig. (*p*)
1	.406	9.458	5	.092

p < .05 = significant contribution

Structure Matrix

	Function 1
AGF1 re-calculated index	.803*
People/dwelling	.455
RADC (m^2 residential floor area/person)	.452
AGF2 village index	.369
SPDC (people/ha)	-.277

* Largest absolute correlation between each variable and any discriminant function

Casewise Statistics

Case Number	Site Name	Actual Group	Highest Group: Predicted Group	P(D>d | G=g) p	df	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid
1	Nahal Oren	1	1	.863	1	.934	.030
2	El-Hemmeh (PPNA)	1	1	.167	1	.998	1.908
3	Shkārat Msaied	1	1	.626	1	.873	.238
4	Beidha (A1)	1	1	.340	1	.995	.910
5	Beidha (A2)	1	1	.925	1	.944	.009
6	Beidha (B2)	1	1	.942	1	.947	.005
7	‘Ain Abu Nekheileh	1	1	.925	1	.963	.009
8	Gilgal I	2	1[a]	.388	1	.743	.746
9	Netiv Hagdud	2	2	.797	1	.944	.066
10	Wadi Hamarash I	1	1	.185	1	.500	1.754
11	Beidha (C2)	1	1	.781	1	.917	.077
12	Ghwair I	2	1[a]	.232	1	.574	1.428
13	El-Hemmeh (LPPNB)	2	2	.520	1	.681	.413
14	Ba'ja	2	2	.187	1	.995	1.741
15	Basta	2	2	.109	1	.997	2.569

Classification Results[b]

	Site Type	Predicted Group Membership 1	Predicted Group Membership 2	Total
Count	1	9	0	9
	2	2	4	6
%	1	100.0	.0	100.0
	2	33.3	66.7	100.0

[a] Misclassified case.
[b] 86.7% of original grouped cases correctly classified.

Table 8.7. Discriminant function analysis - two site type classification system (architecture).

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.712	100.0	100.0	.888

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig. (*p*)
1	.212	16.275	5	.006

$p < .05$ = significant contribution

Structure Matrix

	Function 1
AGF1 re-calculated index	.670
People/dwelling	.345
AGF2 village index	.144
SPDC (people/ha)	-.118
RADC (m^2 residential floor area/person)	-.032

Casewise Statistics

Case Number	Site Name	Actual Group	Highest Group: Predicted Group	Highest Group: P(D>d | G=g) p	Highest Group: P(D>d | G=g) df	Highest Group: P(G=g | D=d)	Highest Group: Squared Mahalanobis Distance to Centroid
1	Nahal Oren	1	1	.064	1	1.000	3.427
2	El-Hemmeh (PPNA)	1	1	.877	1	.999	.024
3	Shkārat Msaied	1	1	.515	1	1.000	.423
4	Beidha (A1)	1	1	.512	1	.991	.430
5	Beidha (A2)	1	1	.858	1	.998	.032
6	Beidha (B2)	1	1	.819	1	.998	.052
7	‘Ain Abu Nekheileh	1	1	.956	1	.999	.003
8	Gilgal I	1	1	.236	1	.941	1.407
9	Netiv Hagdud	1	1	.878	1	.999	.024
10	Wadi Hamarash I	2	2	.960	1	.998	.003
11	Beidha (C2)	2	2	.613	1	.988	.256
12	Ghwair I	2	2	.705	1	.993	.144
13	El-Hemmeh (LPPNB)	2	2	.115	1	.627	2.489
14	Ba'ja	2	2	.613	1	1.000	.255
15	Basta	2	2	.045	1	1.000	4.032

Classification Results[a]

	Site Type	Predicted Group Membership 1	Predicted Group Membership 2	Total
Count	1	9	0	9
	2		6	6
%	1	100.0	.0	100.0
	2		100.0	100.0

[a] 100% of original grouped cases correctly classified.

Table 8.8. Estimates for each variable based on the five site type classification system.

Site type	Case number	Site name	Mean estimates: Total population	People/dwelling	RADC (m² residential floor area/person)	SPDC (people/ha)	Initial growth index: *AGF1 re-calculated*	*AGF2 open*	*AGF2 village*	*AGF2 urban*	Residential area of complete dwellings (m²): *Floor*	*Built*	Proportion (%) in site area[a]: *Built floor area*	*Contemporaneous residential area*: *Built*	*Floor*	Proportion (%) of residential floor area in built floor area*	Contemporaneous dwellings/ha
1	1	Nahal Oren	32	2.6	3.74	642	9.2	.57	16.5	51	9.6	16.34	32.76	36.95	22.66	86.47	245
	2	El-Hemmeh (PPNA)	81	1.2	2.89	808	8.8	.17	12.7	54	4.8	7.56	34.57	35.87	22.73	87.66	73
	3	Shkārat Msaied	109	3.7	3.66	545	11.9	.20	19.6	91	13.5	26.32	29.47	36.73	18.69	79.29	153
	4	Beidha (A1)	72	3.4	3.05	719	9.7	.22	14.5	59	11.6	20.64	34.22	40.45	20.99	85.88	216
	5	Beidha (A2)	97	2.1	3.17	486	13.4	.24	21.3	96	7.3	14.81	29.77	29.84	14.85	66.54	230
	6	Beidha (B2)	93	1.9	3.13	467	13.4	.25	22.1	99	6.5	12.47					250
	7	‘Ain Abu Nekheileh	111	2.2	3.66	926	12.8	.11	11.4	53	8.0	14.47	53.97	54.57	32.13	91.59	432
	Total	N 7															
		Minimum	32	1.2	2.89	467	8.8	.11	11.4	51	4.8	7.56	29.47	29.84	14.85	66.54	73
		Maximum	111	3.7	3.74	926	13.4	.57	22.1	99	13.5	26.32	53.97	54.57	32.13	91.59	432
		Mean	85	2.5	3.33	656	11.3	.25	16.9	72	8.7	16.09	35.79	39.07	22.01	82.91	229
		SD	27	.9	.35	172	2.0	.15	4.2	22	3.0	5.99	9.16	8.34	5.77	8.95	110
2	8	Gilgal I	211	3.3	3.35	528	18.6	.11	20.2	117	12.8	15.95	40.01	20.97	16.58	69.10	168
	9	Netiv Hagdud	241	4.8	4.53	322	17.9	.13	31.5	195	21.3	28.21	23.98	19.02	14.39	100.00	67
	Total	N 2															
		Minimum	211	3.3	3.35	322	17.9	.11	20.2	117	12.8	15.95	23.98	19.02	14.39	69.10	67
		Maximum	241	4.8	4.53	528	18.6	.13	31.5	195	21.3	28.21	40.01	20.97	16.58	100.00	168
		Mean	226	4.1	3.94	425	18.2	.12	25.8	156	17.1	22.08	32.00	20.00	15.49	84.55	118
		SD	21	1.0	.83	146	.5	.02	8.0	55	6.1	8.67	11.33	1.38	1.55	21.85	71
3	10	Wadi Hamarash I	185	3.7	3.21	369	23.4	.17	28.3	158	12.2	21.01	36.56	17.15	11.33	39.73	100
	11	Beidha (C2)	178	5.1	2.95	594	19.7	.11	17.6	97	17.2	29.53	49.67	27.83	16.77	43.40	122
	Total	N 2															
		Minimum	178	3.7	2.95	369	19.7	.11	17.6	97	12.2	21.01	36.56	17.15	11.33	39.73	100
		Maximum	185	5.1	3.21	594	23.4	.17	28.3	158	17.2	29.53	49.67	27.83	16.77	43.40	122
		Mean	181	4.4	3.08	482	21.5	.14	23.0	128	14.7	25.27	43.12	22.49	14.05	41.57	111
		SD	5	1.0	.18	159	2.6	.04	7.5	43	3.5	6.03	9.27	7.55	3.85	2.60	16

* Beidha Subphase B2 proportions not assessed as largely dependent on Beidha Subphase A2.

Site type	Case number	Site name	Mean estimates										Proportion (%) in site area:				
							Initial growth index				Residential area of complete dwellings (m^2)			Contemporaneous residential area			
			Total population	**People/dwelling**	**RADC (m^2 residential floor area/person)**	**SPDC (people/ha)**	*AGF1 re-calculated*	*AGF2 open*	*AGF2 village*	*AGF2 urban*	*Floor*	*Built*	*Built floor area*	*Built*	*Floor*	**Proportion (%) of residential floor area in built floor area**	**Contemporaneous dwellings/ha**
4	12	Ghwair I	506	4.7	3.32	382	21.2	.06	27.4	214	15.1	24.04	29.21	19.21	12.10	53.26	80
	13	El-Hemmeh (LPPNB)	664	2.7	3.35	664	26.5	.03	15.7	134	8.7	15.32	61.12	32.57	21.33	44.74	246
	14	Ba'ja	603	3.4	4.13	663	36.1	.04	22.6	190	13.5	23.20	58.03	29.81	18.24	40.28	128
	Total	N 3															
		Minimum	506	2.7	3.32	382	21.2	.03	15.7	134	8.7	15.32	29.21	19.21	12.10	40.28	80
		Maximum	664	4.7	4.13	664	36.1	.06	27.4	214	15.1	24.04	61.12	32.57	21.33	53.26	246
		Mean	591	3.6	3.60	569	27.9	.04	21.9	180	12.4	20.85	49.45	27.20	17.22	46.09	151
		SD	80	1.1	.46	163	7.5	.02	5.9	41	3.4	4.81	17.60	7.05	4.70	6.59	86
5	15	Basta	6773	5.7	3.50	521	42.3	.00	19.7	368	26.3	37.11	53.64	36.95	17.68	54.50	92
	Total	N 1															
		Minimum	5693	4.8	2.90	438	36.6	.00	16.6	329							
		Maximum	7854	6.6	4.00	604	48.1	.00	22.8	408							
		Mean	6773	5.7	3.50	521	42.3	.00	19.7	368	26.3	37.11	53.64	36.95	17.68	54.50	92
		SD															
Total	N	15															
	Minimum		32	1.2	2.89	322	8.8	.00	11.4	51	4.8	7.56	23.98	17.15	11.33	39.73	67
	Maximum		7854	6.6	4.53	926	48.1	.57	31.5	408	21.3	29.53	61.12	54.57	32.13	100	432
	Mean		664	3.4	3.44	576	19.0	.16	20.1	132	12.6	20.47	40.50	31.28	18.61	67.32	174
	SD		1702	1.3	.45	166	9.8	.14	5.7	85	5.8	7.73	12.27	10.23	5.30	21.24	98

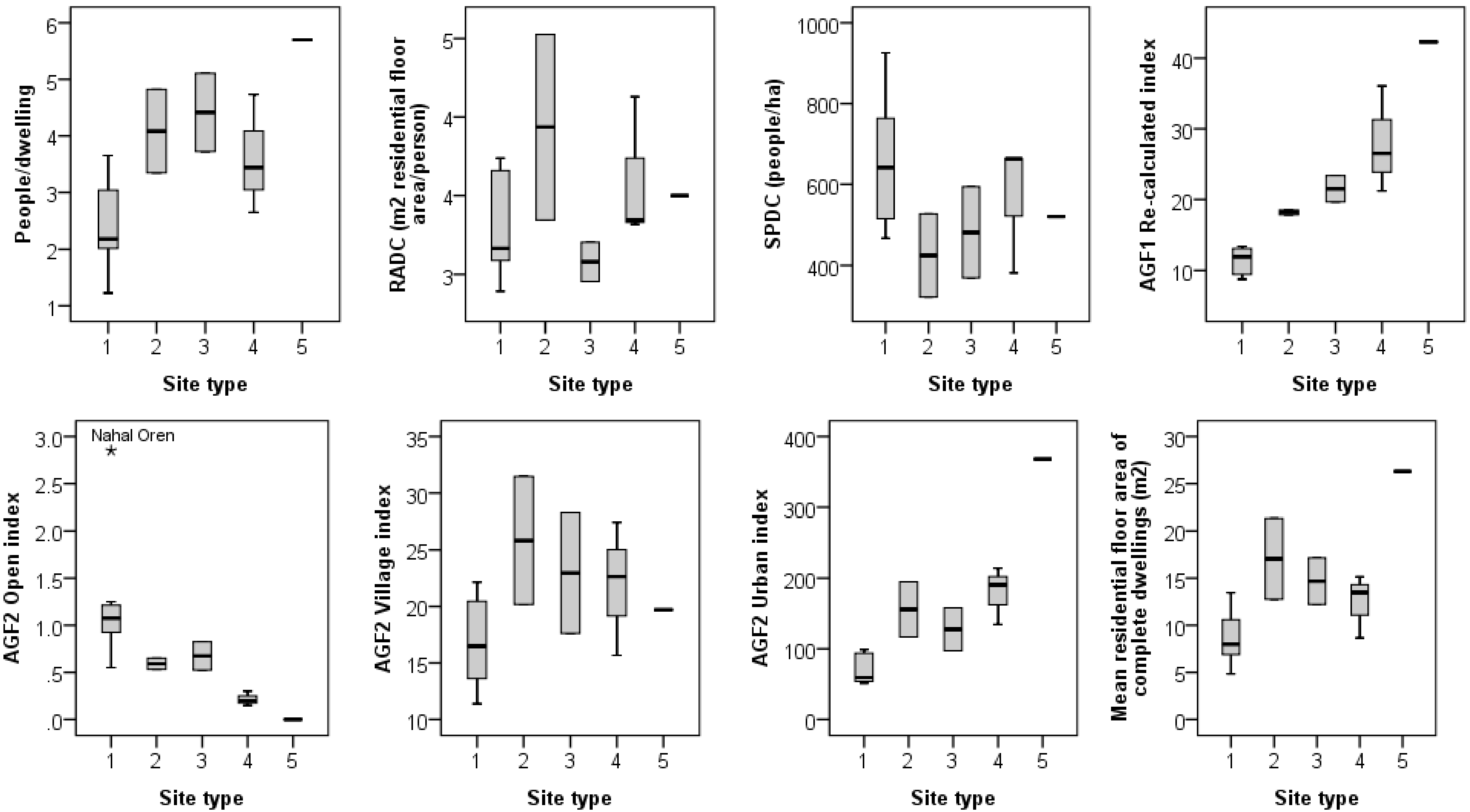


Figure 8.4. Box plots of estimates for each variable based on the five site type classification system.

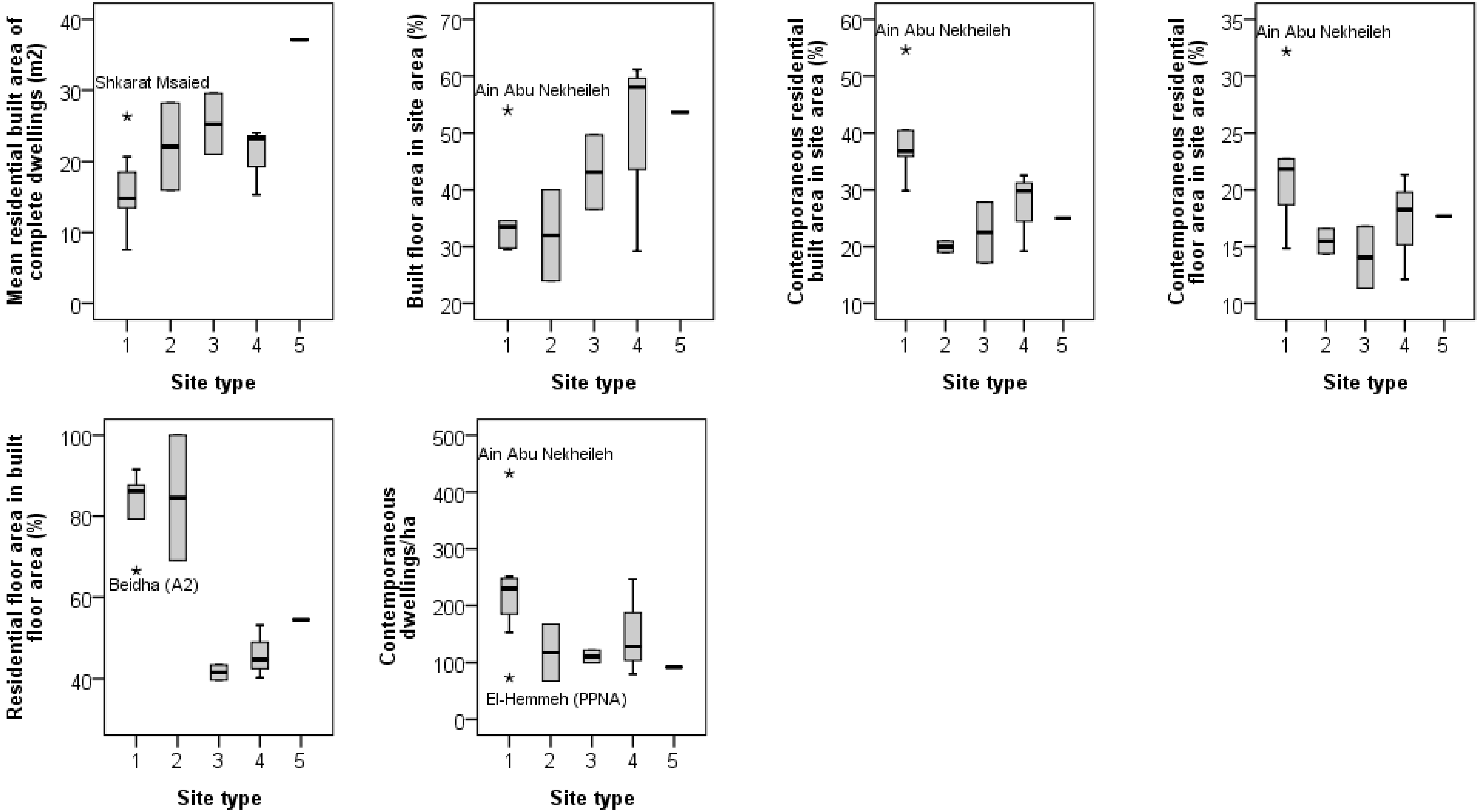


Figure 7.40. Box plots of estimates for each variable based on the five site type classification system (continued).

8.5 Analysis of variance (ANOVA): one-way ANOVA and Kruskal-Wallis

Analysis of variance tests (one-way ANOVA and the non-parametric equivalent: the Kruskal-Wallis test) were conducted to determine whether significant differences occur in the mean and median values of variables between the five site types (VanPool and Leonard 2011) (see Appendix D). The purpose of these tests is to determine whether site type and/or universal constants could be developed for each of the variables. A significance value (p) of less than .05 indicates significant difference.

The one-way ANOVA indicated significant differences between the five site types in the mean values of six variables: people per dwelling (p = .029); initial growth indices for AGF1 re-calculated (p = .000) and AGF2 urban (p = .000); the mean residential floor area of complete dwellings (p = .007); the proportion of contemporaneous residential built area in site area (p = .040); and the proportion of residential floor area in built floor area (p = .010) (Table 8.9).

The Kruskal-Wallis test indicated significant differences between the five site types in the median values of five variables: initial growth indices for AGF1 re-calculated (p = .015), AGF2 open (p = .024) and AGF2 urban (p = .026); the proportion of contemporaneous residential built area in site area (p = .044); and the proportion of residential floor area in built floor area (p = .036) (Table 8.10).

Indication of significant differences supports the creation of site type constants for these variables. In addition, high significance values could support the creation of universal constants for some variables, including population density (SPDC) (p = .446 and .448); residential floor area per person (RADC) (p = .359 and .384); the proportion of built floor area in site area (p = .356 and .544); and the number of contemporaneous dwellings per hectare (p = .378 and .383).

Table 8.9. Analysis of variance: one-way ANOVA (variables with significant difference highlighted in grey).

Variable		Statistics	Sum of Squares	df	Mean Square	F	Sig. (*p*)*
People/dwelling		Between Groups	14.688	4	3.672	4.234	.029
		Within Groups	8.672	10	.867		
		Total	23.359	14			
RADC (m^2 residential floor area/person)		Between Groups	.919	4	.230	1.229	.359
		Within Groups	1.871	10	.187		
		Total	2.790	14			
SPDC (people/ha)		Between Groups	111802.330	4	27950.583	1.013	.446
		Within Groups	276028.763	10	27602.876		
		Total	387831.093	14			
Initial growth index	AGF1 re-calculated	Between Groups	1209.675	4	302.419	20.861	.000
		Within Groups	144.965	10	14.497		
		Total	1354.640	14			
	AGF2 open	Between Groups	.128	4	.032	2.366	.123
		Within Groups	.135	10	.014		
		Total	.263	14			
	AGF2 village	Between Groups	164.481	4	41.120	1.380	.309
		Within Groups	298.051	10	29.805		
		Total	462.531	14			
	AGF2 urban	Between Groups	88826.946	4	22206.736	19.880	.000
		Within Groups	11170.336	10	1117.034		
		Total	99997.282	14			
Mean residential area of complete dwellings (m^2)	Floor	Between Groups	340.109	4	85.027	6.780	.007
		Within Groups	125.403	10	12.540		
		Total	465.512	14			
	Built	Between Groups	463.060	4	115.765	3.101	.067
		Within Groups	373.274	10	37.327		
		Total	836.335	14			
Proportion in site area (arcsine):	Built floor area	Between Groups	.074	4	.018	1.254	.356
		Within Groups	.133	9	.015		
		Total	.206	13			
	Contemporaneous residential built area	Between Groups	.103	4	.026	3.982	.040
		Within Groups	.058	9	.006		
		Total	.161	13			
	Contemporaneous residential floor area	Between Groups	.022	4	.006	1.417	.304
		Within Groups	.035	9	.004		
		Total	.058	13			
Proportion of residential floor area in built floor area (arcsine)		Between Groups	.695	4	.174	6.323	.010
		Within Groups	.247	9	.027		
		Total	.942	13			
Contemporaneous dwellings/ha		Between Groups	43390.453	4	10847.613	1.177	.378
		Within Groups	92185.664	10	9218.566		
		Total	135576.117	14			

* $p < .05$ indicates significant difference.

Table 8.10. Analysis of variance: Kruskal-Wallis test (variables with significant difference highlighted in grey).

Variable			Chi-Square	df	Sig. (p)*
People/dwelling			8.804	4	.066
RADC (m^2 residential floor area/person)			4.167	4	.384
SPDC (people/ha)			3.699	4	.448
Initial growth index	AGF1 re-calculated		12.264	4	.015
	AGF2 open		11.229	4	.024
	AGF2 village		4.481	4	.345
	AGF2 urban		11.057	4	.026
Mean residential area of complete dwellings (m^2)		Floor	8.345	4	.080
		Built	6.545	4	.162
Proportion in site area (arcsine):	Built floor area		3.086	4	.544
	Contemporaneous residential built area		9.771	4	.044
	Contemporaneous residential floor area		6.038	4	.196
Proportion of residential floor area in built floor area (arcsine)			10.257	4	.036
Contemporaneous dwellings/ha			4.170	4	.383

* $p < .05$ indicates significant difference.

8.6 Effect size (ETA squared/eta^2)

ETA squared (eta^2) values are a measure of effect size. An eta^2 value is the proportion of variability in the dependent variable (i.e. people per dwelling) accounted for by variation in the independent variable (i.e. the grouping variable: site type). Eta^2 values were produced in SPSS via an ANOVA test. In general, an eta^2 value of around 1% indicates a small effect; around 6% indicates a medium effect; and around 14% indicates a large effect (Cohen 1988).

All eta^2 values exceed the threshold for a large effect size (eta^2 ≥ 14%) (Table 8.11). This indicates that differences in site type have a large effect on the values of all variables, supporting the development of site type constants.

Extremely large effect sizes were produced for initial growth indices for AGF1 re-calculated (89.3%) and AGF2 urban (88.8%); the mean residential floor area of complete dwellings (73.1%); and the proportion of residential floor area in built floor area (73.8%). Almost all of the variation in these variables appears to be due to variations in site type. This supports the development of site type constants for these variables.

Table 8.11. Measures of effect size (eta^2).

Variable		Measures of Association	
		Eta	*Eta^2**
People/dwelling		.793	.629
RADC (m^2 residential floor area/person)		.574	.330
SPDC (people/ha)		.537	.288
Initial growth index	AGF1 re-calculated	.945	.893
	AGF2 open	.697	.486
	AGF2 village	.596	.356
	AGF2 urban	.942	.888
Mean residential area of complete dwellings (m^2)	Floor	.855	.731
	Built	.744	.554
Proportion in site area (arcsine):	Built floor area	.598	.358
	Contemporaneous residential built area	.799	.639
	Contemporaneous residential floor area	.622	.386
Proportion of residential floor area in built floor area (arcsine)		.859	.738
Contemporaneous dwellings/ha		.566	.320

* Proportion of variation due to site type.

8.7 Proposed site type classification system

A new five site type classification system is proposed in this investigation for PPN central and southern Levantine villages based on the results of discriminant function analysis. The five types include:

1. Small (< 0.4 ha) villages of predominantly curvilinear architecture;
2. Large (≥ 0.4 ha) villages of predominantly curvilinear architecture;
3. Small (≤ 0.5 ha) villages of predominantly rectilinear architecture;
4. Large (0.6-6 ha) villages of predominantly rectilinear architecture; and,
5. Very large (≥ 7 ha) villages of predominantly rectilinear architecture.

8.8 Proposed site type and universal constants

Analysis of variance indicated significant differences between the five site types in the values of several variables, including initial growth indices for AGF1 re-calculated, AGF2 open and AGF2 urban; the proportion of contemporaneous residential built area in site area; and the proportion of residential floor area in built floor area. Analysis of ANOVA effect size indicated that variations in site type had a large effect on all variables. Based on these analyses, site type constants are proposed for all variables. In addition, universal constants are proposed for application to sites where site type may be unknown. Site type constants are based on the mean, minimum and maximum values for the corresponding site type. Universal constants are based on the mean, minimum and maximum values of variables across all site types (Table 8.12).

Table 8.12. Proposed minimum, maximum and mean site type and universal constants.

Site type	Statistic	People/dwelling	RADC (m^2 residential floor area/person)	SPDC (people/ha)	Initial growth index				Mean residential area of complete dwellings (m^2)		Proportion in site area:			Proportion of residential floor area in built floor area	Contemporaneous dwellings/ha
					AGF1 re-calculated	*AGF2 open*[a]	*AGF2 village*	*AGF2 urban*[b]	*Floor*	*Built*	*Built floor area*	*Contemporaneous residential built area: Built*	*Contemporaneous residential built area: Floor*		
1	Minimum	1.2	2.89	467	8.8	.11	11.4	51	4.8	7.6	29.47	29.84	14.85	66.54	73
	Maximum	3.7	3.74	926	13.4	.57	22.1	99	13.5	26.3	53.97	54.57	32.13	91.59	432
	Mean	**2.5**	**3.33**	**656**	**11.3**	.25	**16.9**	**72**	**8.7**	**16.1**	**35.79**	**39.07**	**22.01**	**82.91**	**229**
2	Minimum	3.3	3.35	322	17.9	.11	20.2	117	12.8	16.0	23.98	19.02	14.39	69.10	67
	Maximum	4.8	4.53	528	18.6	.13	31.5	195	21.3	28.2	40.01	20.97	16.58	100.00	168
	Mean	**4.1**	**3.94**	**425**	**18.2**	.12	**25.8**	**156**	**17.1**	**22.1**	**32.00**	**20.00**	**15.49**	**84.55**	**118**
3	Minimum	3.7	2.95	369	19.7	.11	17.6	97	12.2	21.0	36.56	17.15	11.33	39.73	100
	Maximum	5.1	3.21	594	23.4	.17	28.3	158	17.2	29.5	49.67	27.83	16.77	43.40	122
	Mean	**4.4**	**3.08**	**482**	**21.5**	**.14**	**23.0**	**128**	**14.7**	**25.3**	**43.12**	**22.49**	**14.05**	**41.57**	**111**
4	Minimum	2.7	3.32	382	21.2	.03	15.7	134	8.7	15.3	29.21	19.21	12.10	40.28	80
	Maximum	4.7	4.13	664	36.1	.06	27.4	214	15.1	24.0	61.12	32.57	21.33	53.26	246
	Mean	**3.6**	**3.60**	**569**	**27.9**	**.04**	**21.9**	**180**	**12.4**	**20.9**	**49.45**	**27.20**	**17.22**	**46.09**	**151**
5[c]	Minimum	4.8	2.93	438	36.6	.00	16.6	329	18.9	27.0	-	-	*12.42*	-	-
	Maximum	6.6	4.04	604	48.1	.00	22.8	408	33.7	47.2	-	-	*21.90*	-	-
	Mean	**5.7**	**3.49**	**521**	**42.3**	**.00**	**19.7**	**368**	**26.3**	**37.1**	**53.64**	**36.95**	**17.68**	**54.50**	**92**
Universal	Minimum	1.2	2.89	322	8.8	.00	11.4	51	4.8	7.6	23.98	17.15	11.33	39.73	67
	Maximum	6.6	4.53	926	48.1	.57	31.5	408	21.3	29.5	61.12	54.57	32.13	100.00	432
	Mean	**3.4**	**3.44**	**576**	**19.0**	.16	**20.1**	**132**	**12.6**	**20.5**	**40.50**	**31.28**	**18.61**	**67.32**	**174**

[a] Based on Nahal Oren only.

[b] Based on Basta only.

[c] All values based on Basta only. Minimum and maximum values for the proportion of contemporaneous residential floor area in site area are required for the SPF Method 1. These could not be established from the Basta evidence and are instead based on the proportional differences between the mean and minimum/maximum values for Site Type 4, which produced a comparable mean value.

8.9 Summary

Statistical analysis revealed correlations between variables (i.e. people per dwelling, RADC, SPDC, etc.) and sites of different site size and predominant architectural form. Based on these correlations, a five type classification system is proposed for PPN central and southern Levantine villages, including (1) small (< 0.4 ha) and (2) large (≥ 0.4 ha) villages of predominantly curvilinear architecture; and (3) small (≤ 0.5 ha), (4) large (0.6-6 ha) and (5) very large ("mega": ≥ 7 ha) villages of predominantly rectilinear architecture. Site type and universal constants were developed for each variable (see Table 8.12). The site type classification system and constants developed in this chapter form the basis of methodologies for systematic reconstruction of population estimates explored in the following chapter.

9 Estimates of PPN Central and Southern Levantine Villages

This chapter presents descriptive statistics for site extent, predominant architectural form and site type for the PPN central and southern Levantine village database (Appendix E.1). This is followed by an assessment of the results of systematic methodologies to determine those for inclusion in the final estimate range. Statistical analyses are conducted to determine whether significant differences occur between the results of micro-level and systematic methodologies in order to select the most suitable methodologies for inclusion in the final estimate ranges. Population estimates are assessed against hypothesised group size thresholds and additional thresholds are suggested. A summary of density estimates per site type and population growth rates are presented. Finally, a series of site type and universal formulae are proposed for estimating PPN village populations in future.

9.1 Descriptive statistics per PPN period

9.1.1 Site frequency

The village database includes 71 villages, of which 46 are dated to a single PPN period; 16 to two different periods; eight to three different periods; and one to four different periods. This produces a total database of 106 villages/village phases. Almost a third date to the LPPNB (*n* = 32; 30.2%) and a further quarter to the MPPNB (*n* = 28; 26.4 %) (Figures 9.1-9.2). The smallest proportion dates to the EPPNB (*n* = 9; 8.5%). Sites identified as terminating early in a period (i.e. Tell Aswad was abandoned early in the LPPNB) (Helmer and Gourichon 2008) were not included in that period in order to more accurately reflect long-term population dynamics.

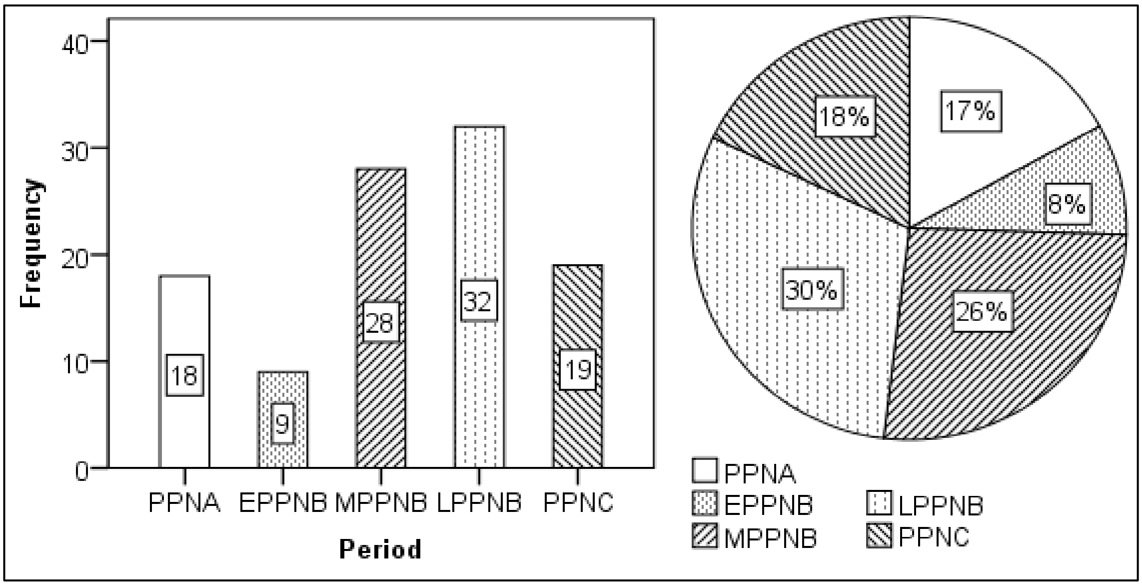


Figure 9.1. PPN central and southern Levantine villages per period.

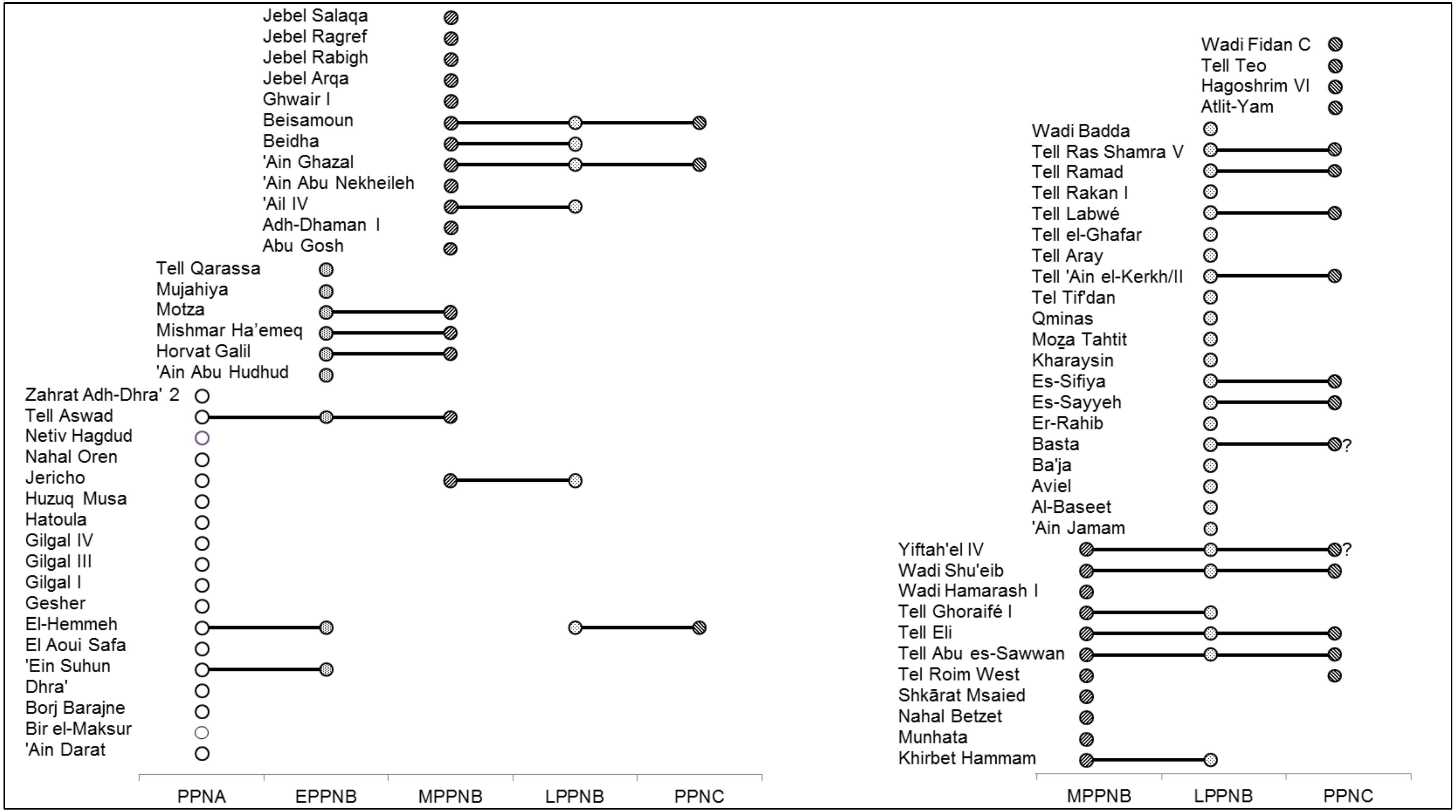


Figure 9.2. Temporal distribution of PPN central and southern Levantine villages (? = questionable PPNC date).

9.1.2 Site extent

Site extent estimates range from 0.05 hectares to 16 hectares, with a mean of 2.81 hectares and a median of 1.5 hectares. Mean site size estimates increase gradually from the PPNA (0.44 ha) to the MPPNB (1.52 ha), with considerable increase occurring between the MPPNB and LPPNB (5.21 ha). Mean estimated site size decreases between the LPPNB and PPNC (3.87 ha) (Figure 9.3). This pattern of settlement size increase and decline compares well with previous investigations of changing site extent throughout the PPN (Kuijt 2008a, p.292).

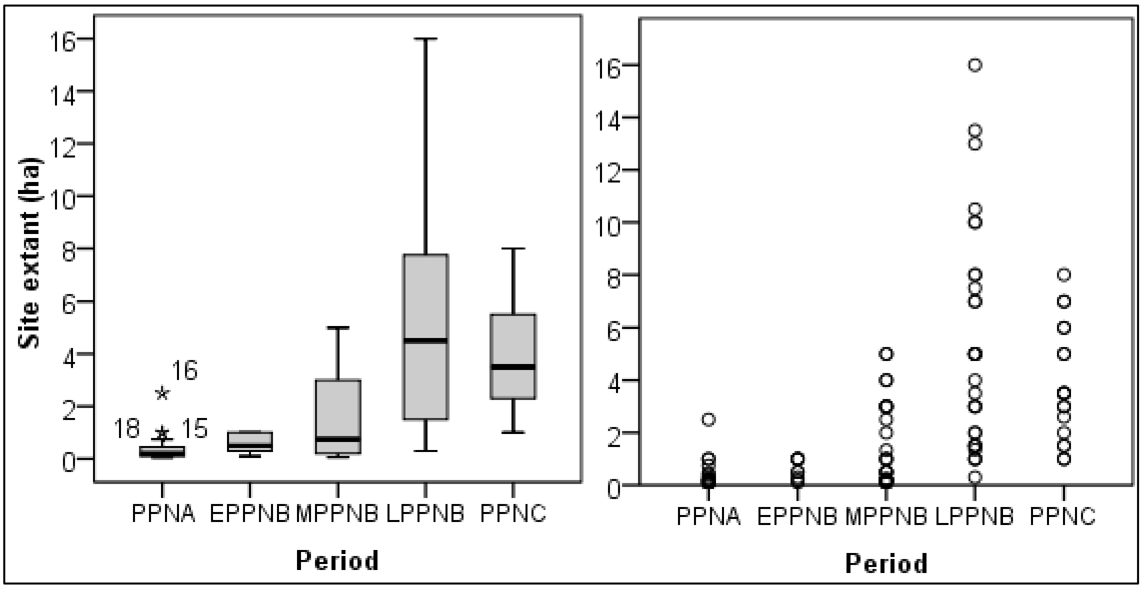


Figure 9.3. Site extent (ha) per period (* 15: Huzuq Musa; 16: Jericho; 18: Tell Aswad IA).

9.1.3 Predominant architectural form

The majority of villages have predominantly rectilinear architecture (*n* = 64; 60.4%), followed by curvilinear architecture (*n* = 33; 31.1%) (Figure 9.4). The predominant architectural form could not be identified for nine (8.5%) villages. All villages dated to the PPNA contain predominantly curvilinear architecture. Curvilinear forms continue through the EPPNB (*n* = 6; 75%) and MPPNB (*n* = 9; 32.14%). No villages were identified as having predominantly curvilinear architecture during the LPPNB or PPNC. Villages with predominantly rectilinear architecture emerge during the EPPNB (*n* = 2; 22.2%). Rectilinear architecture becomes increasingly common during the MPPNB (*n* = 15; 53.57%) and forms the predominant type during the LPPNB (*n* = 30; 93.75%) and PPNC (*n* = 17; 89.47%).

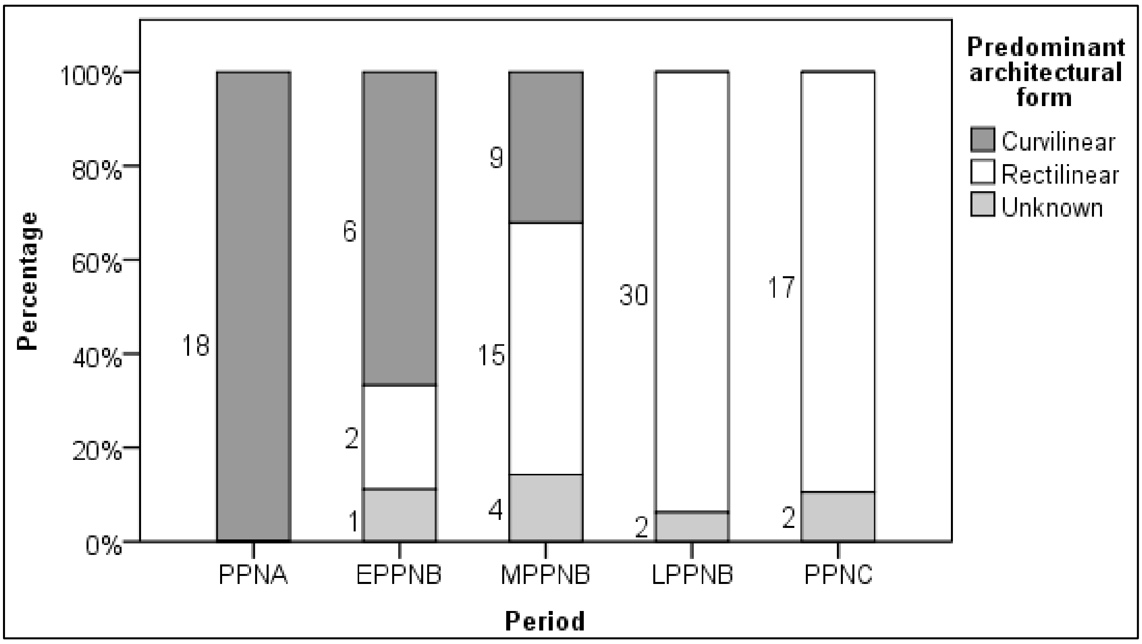


Figure 9.4. Predominant architectural form per period.

9.1.4 Site type

Villages were categorised into five types based on micro-level analysis (see Section 8.4):

Type 1: small (< 0.4 ha) villages of predominantly curvilinear architecture

Type 2: large (≥ 0.4 ha) villages of predominantly curvilinear architecture

Type 3: small (≤ 0.5 ha) villages of predominantly rectilinear architecture

Type 4: large (0.6-6 ha) villages of predominantly rectilinear architecture

Type 5: very large (≥ 7 ha) villages of predominantly rectilinear architecture

Type 4 villages were most frequent (*n* = 47; 44.3%), followed by Type 1 villages (*n* = 23; 21.7%) (Figures 9.5-9.6). Low frequencies were recorded for Type 2 (*n* = 10; 9.4%) and Type 5 villages (*n* = 14; 13.2%). Only three Type 3 villages were recorded (2.8%). Of these, two were analysed at the micro-level (Wadi Hamarash I and Beidha Subphase C2). It is possible that several Type 3 villages have been incorrectly classified as Type 4 villages as a result of site extent overestimation where predominantly rectilinear architecture occurs. Site type could not be determined for nine (8.5%) villages as the predominant architectural form could not be established.

The PPNA contains site types with curvilinear architecture only (Types 1: *n* = 12, 66.7% and 2: *n* = 6, 33.3%). Type 4 villages appear during the EPPNB (*n* = 2, 22.2%) with the introduction of rectilinear architecture and form the predominant type from the MPPNB (*n* = 13, 46.4%). No LPPNB or PPNC villages were categorised as Type 1 or 2 (curvilinear architecture). Type 5 villages ("mega-sites") appear during the LPPNB (*n* = 11, 34.4%), although few appear to maintain such large site extents during the PPNC (*n* = 3, 15.8%).

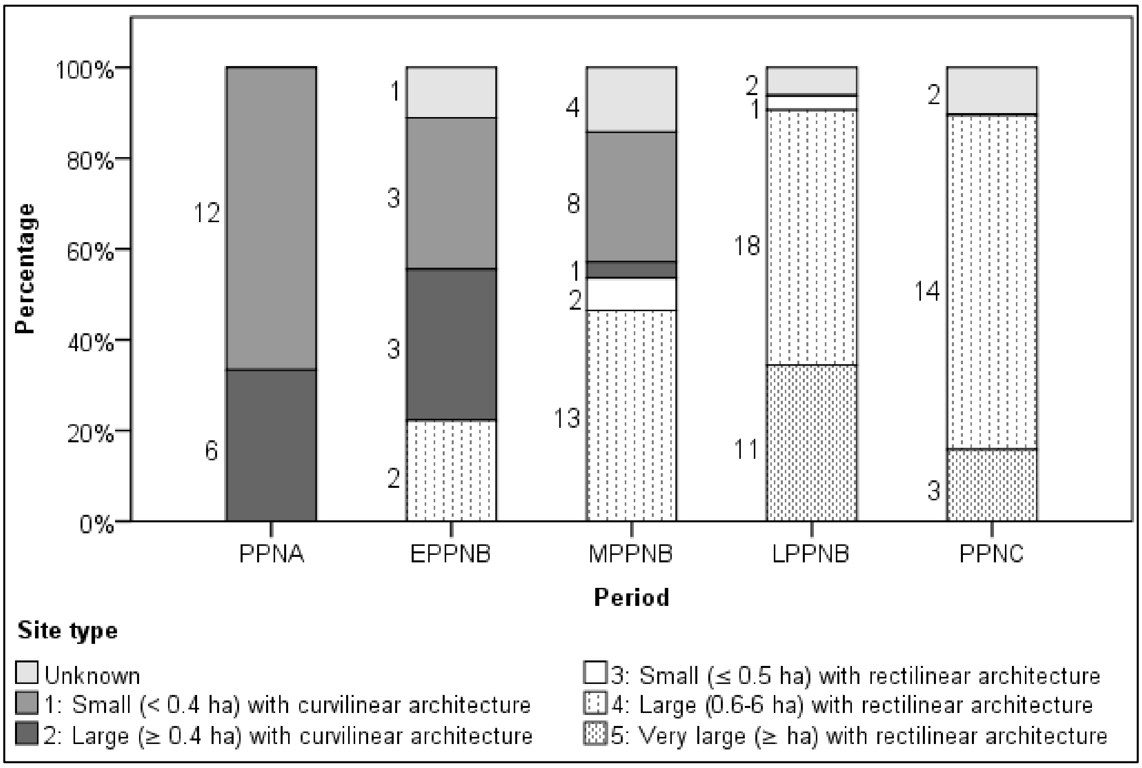


Figure 9.5. Site type frequencies.

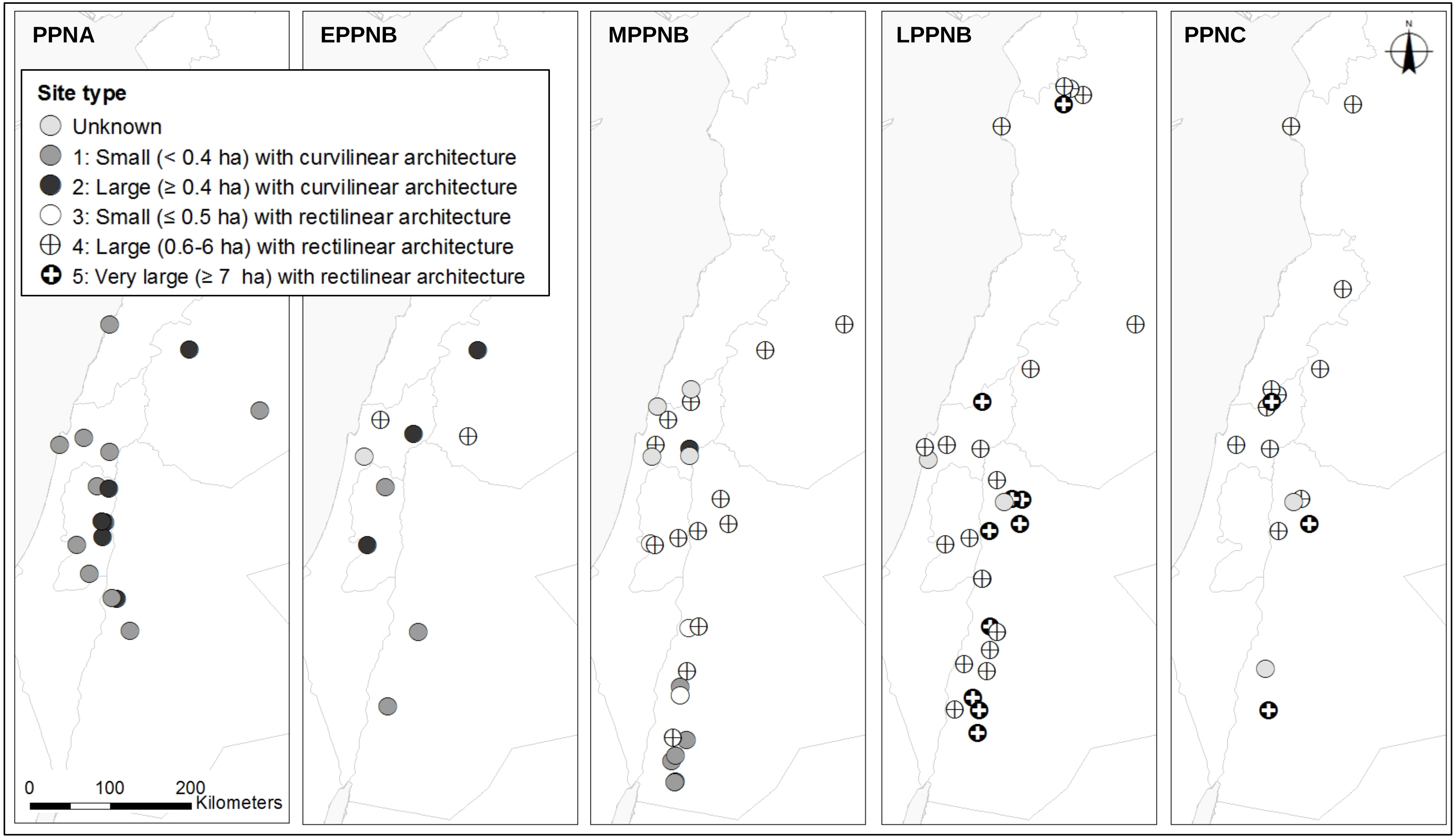


Figure 9.6. Site type per period.

9.2 Assessment of systematic methodologies for inclusion in final estimates

Several systematic methodologies (Table 9.1) were applied to the PPN village database to rapidly estimate population from total site extent and an assigned site type (Appendix E.2).

Table 9.1. Methodologies for systematically estimating PPN village population parameters.

	Method	Constants required	Data produced
1	Regional population density coefficient (RPDC)	• number of contemporaneous dwellings per hectare • number of people per dwelling	• population size • total number of contemporaneous dwellings
2	Residential built area proportions (RBAP)	• proportion of contemporaneous residential built area in site area • mean residential built area of complete dwellings • number of people per dwelling	• population size • total number of contemporaneous dwellings • total contemporaneous residential built area
3	Residential floor area proportions (RFAP)	• proportion of contemporaneous residential floor area in site area • residential floor area per person	• population size • total contemporaneous residential floor area
4	Storage provisions formula (SPF)	• probable amount of storage provisions within the residential floor area • proportion of contemporaneous residential floor area in site area (Method 1) • mean residential floor area of complete dwellings (Method 2) • *mean values for the total number of contemporaneous dwellings derived from the RPDC and RBAP methods (Method 2)*	• population size (Methods 1 and 2) • number of people per dwelling (Method 2)
5	Settlement population density coefficient (SPDC)	• settlement population density coefficient (people per hectare)	• population size
6	Naroll's (1962) allometric growth formula (AGF1)	• $P = (A/a)^{1/0.84195}$ • proportion of built floor area in site area • AGF1 re-calculated initial growth index	• population size • total built floor area
7	Wiessner's (1974) village allometric growth formula (AGF2)	• $P = (A/a)^{1/1}$ • AGF2 village initial growth index	• population size

For villages estimated at the micro-level, the SPF micro-level population estimates were considered most valid and form the final estimate range (see Section 10.2.1). These estimates are also assigned to the succeeding phases of the same site where site extent estimates remain constant (i.e. PPNA/EPPNB el-Hemmeh; LPPNB/PPNC el-Hemmeh). To establish the most suitable methodologies for inclusion in the final estimate ranges of all other villages, statistical techniques were employed to identify systematic methods that produce estimates that differ significantly from the micro-level estimate range (Figure 9.7; Appendix E.3). In addition, the results of each method are assessed to identify those which produce excessive, and thus, ineffectual population estimate ranges.

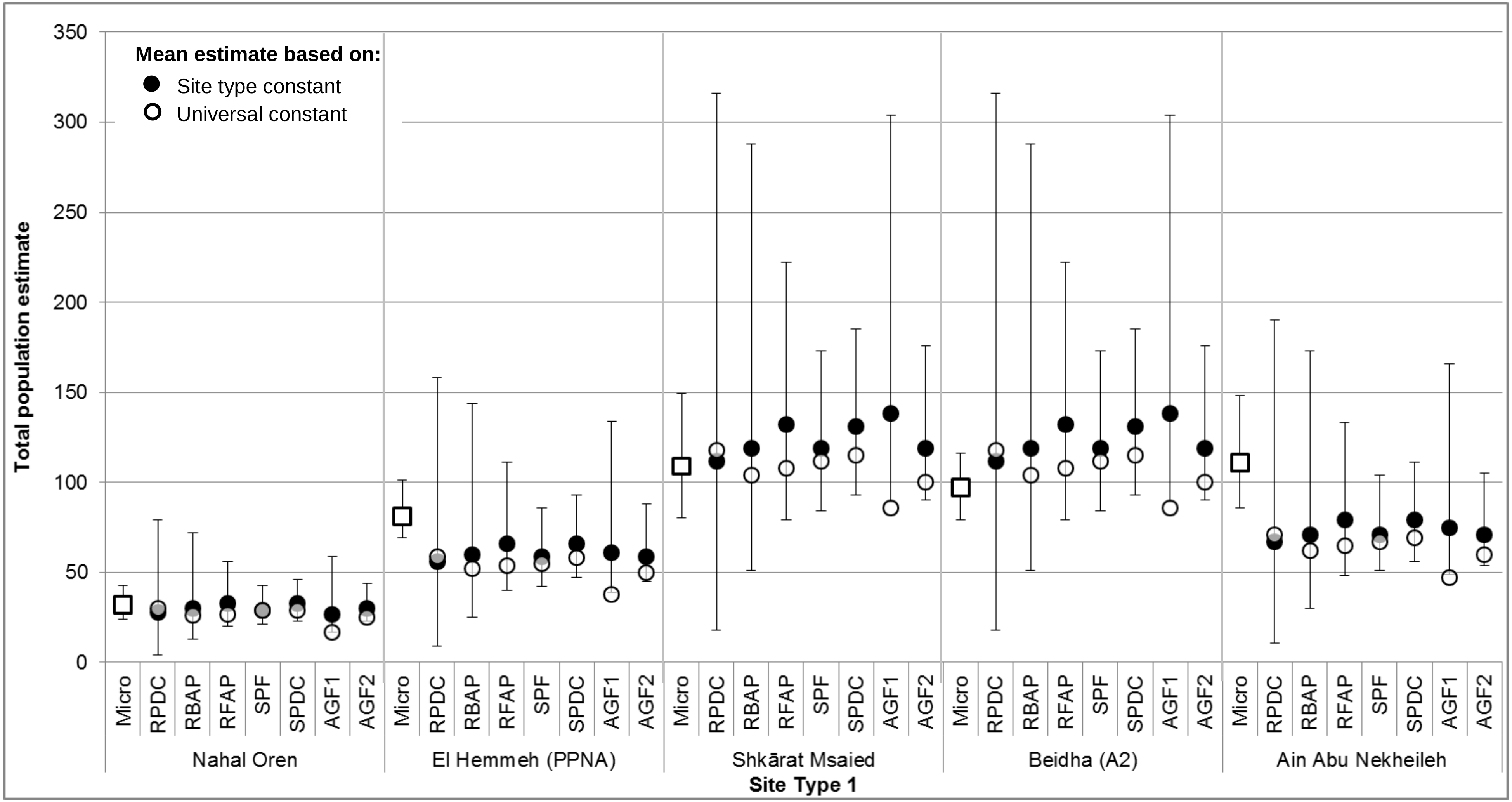


Figure 9.7. Comparison of mean micro-level estimates with mean estimates derived from systematic methodologies. Error bars display minimum to maximum range of estimates based on site type constants.

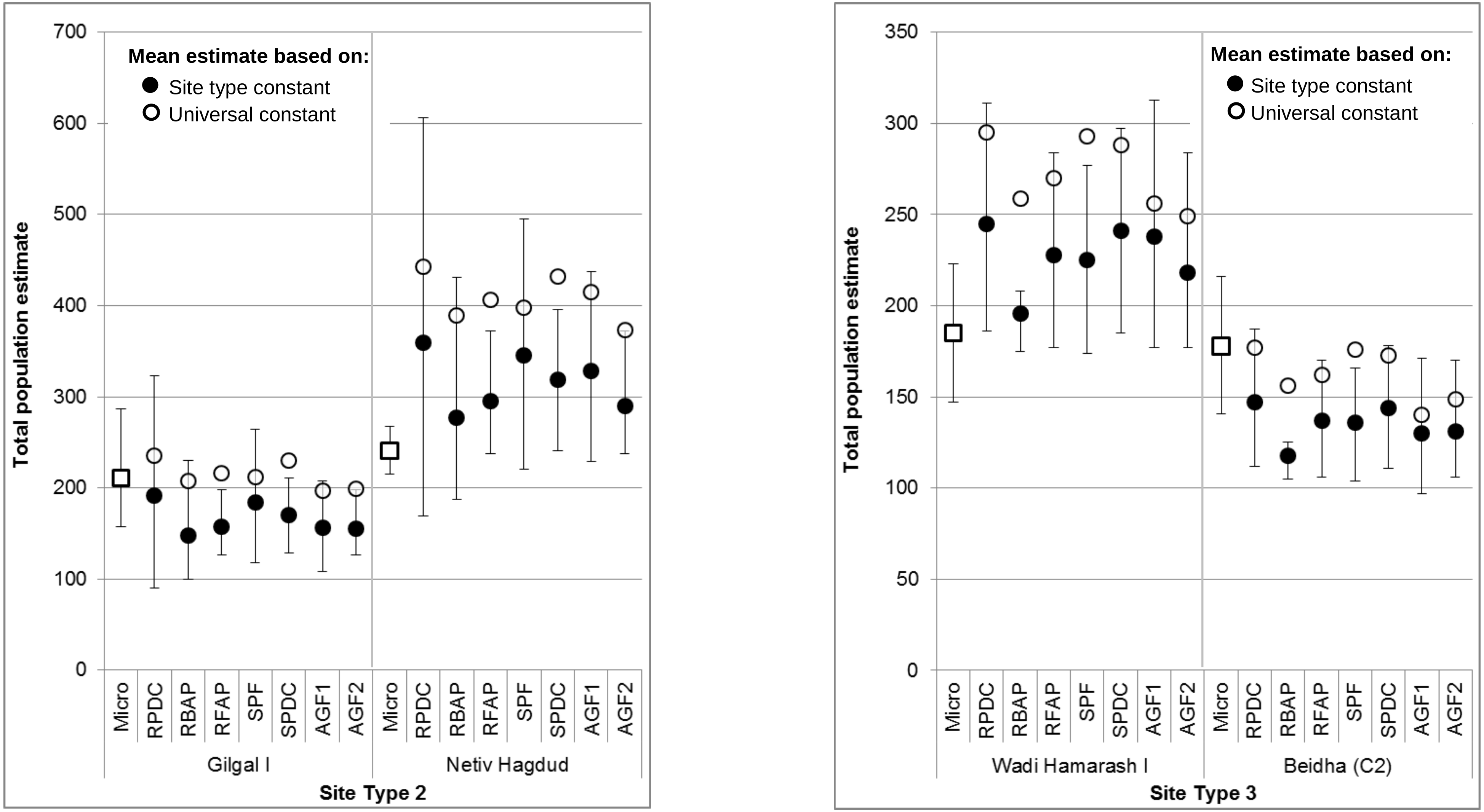


Figure 9.7. Comparison of mean micro-level estimates with mean estimates derived from systematic methodologies. Error bars display minimum to maximum range of estimates based on site type constants (continued).

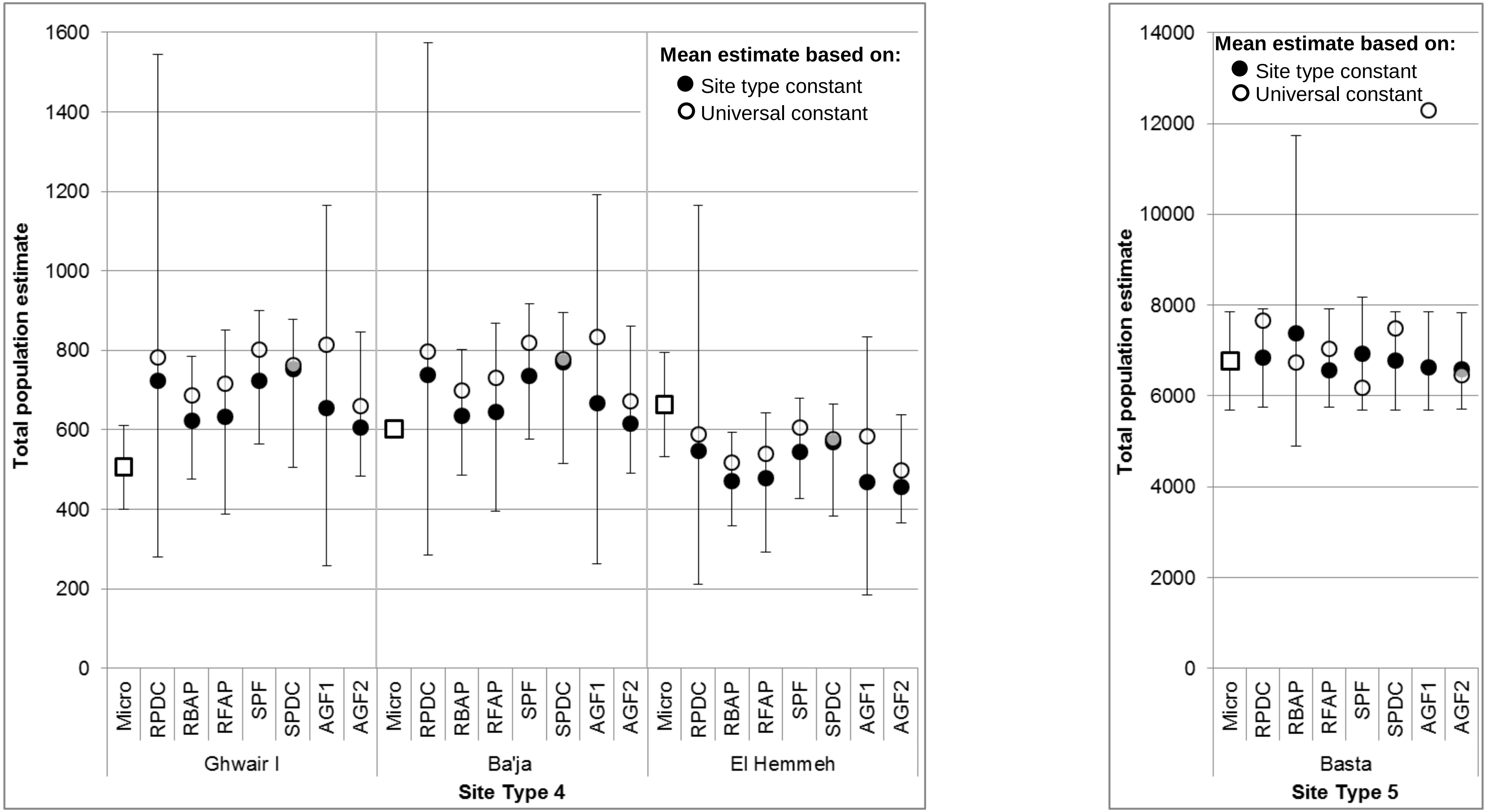


Figure 9.7. Comparison of mean micro-level estimates with mean estimates derived from systematic methodologies. Error bars display minimum to maximum range of estimates based on site type constants (continued).

9.2.1 Statistical analysis

Paired-samples t tests and Wilcoxon signed-rank tests were conducted in SPSS to determine whether there are significant differences between micro-level estimates and estimates derived from systematic methods in order to eliminate methods from the final estimate range (Appendix E.3). Paired-samples t tests compare the means of values from two related samples, whilst the Wilcoxon signed-rank test compares the median of values (Geert van den Berg 2014; 2016). A significance value (p) of less than .05 indicates a significant difference.

Tests indicated no significant differences between the micro-level estimates and estimates derived from systematic methods based on either the site type or universal constants (Table 9.2). However, the paired-samples t test indicated statistically significant differences between the minimum and maximum micro-level and RPDC estimates (min: $t = 2.611$, $df = 12$, $p = .023$; max: $t = -2.731$, $df = 12$, $p = .018$), and the maximum micro-level and AGF1 estimates ($t = -2.301$, $df = 12$, $p = .040$).

The Wilcoxon signed-rank test also indicated statistically significant differences between the minimum and maximum micro-level and RPDC estimates (min: $Z = -2.411$, $p = .016$; max: $Z = -3.111$, $p = .002$), and the maximum micro-level and AGF1 estimates ($Z = -2.271$, $p = .023$). In addition, significant differences were identified between the minimum micro-level and RBAP estimates ($Z = -2.274$, $p = .023$).

The statistically significant differences between micro-level estimates and those derived from the RPDC, AGF1 and RBAP methods indicate that these methods are unsuitable for systematically estimating PPN village populations. An assessment of the estimate ranges resulting from these methods further supports their exclusion from the final estimate range.

Table 9.2. Tests for significant difference between micro-level and systematic estimates (methods with statistically significant differences highlighted in grey).

Difference between min/max/mean micro-level estimate and:		Paired-samples t test - test statistics: Paired Differences *Mean*	*SD*	*SE*	*95% CI Lower*	*95% CI Upper*	*t*	*df*	*Sig. (2-tailed) (p)*[a]	Wilcoxon signed-rank test - test statistics: *Z*	*Asymp. Sig. (2-tailed) (p)*[a]
RPDC	Min	81.00	111.84	31.02	13.42	148.58	2.611	12	.023	-2.411	.016
	Max	-250.92	331.23	91.87	-451.08	-50.76	-2.731	12	.018	-3.111	.002
	Mean	-28.62	88.92	24.66	-82.35	25.12	-1.160	12	.269	-.804	.422
	Universal[b]	-122.77	255.91	70.98	-277.42	31.88	-1.730	12	.109	-1.572	.116
RBAP	Min	97.23	221.46	61.42	-36.60	231.06	1.583	12	.139	-2.274	.023
	Max	-343.00	1071.81	297.27	-990.69	304.69	-1.154	12	.271	-1.503	.133
	Mean	-35.15	186.23	51.65	-147.69	77.39	-.681	12	.509	-.105	.917
	Universal	-16.85	87.36	24.23	-69.63	35.94	-.695	12	.500	-.175	.861
RFAP	Min	36.08	83.83	23.25	-14.58	86.74	1.552	12	.147	-1.452	.147
	Max	-48.85	116.57	32.33	-119.29	21.60	-1.511	12	.157	-1.363	.173
	Mean	15.85	93.09	25.82	-40.41	72.10	.614	12	.551	-.070	.944
	Universal	-49.69	111.43	30.91	-117.03	17.64	-1.608	12	.134	-1.049	.294
SPF	Min	3.54	60.65	16.82	-33.11	40.19	.210	12	.837	-.902	.367
	Max	-78.54	150.35	41.70	-169.39	12.32	-1.883	12	.084	-1.490	.136
	Mean	-33.15	94.47	26.20	-90.24	23.93	-1.265	12	.230	-.804	.421
	Universal	-6.31	207.18	57.46	-131.50	118.89	-.110	12	.914	-.419	.675
SPDC	Min	10.08	59.82	16.59	-26.07	46.23	.607	12	.555	-.629	.529
	Max	-43.92	123.07	34.13	-118.29	30.45	-1.287	12	.222	-.734	.463
	Mean	-29.85	91.95	25.50	-85.41	25.72	-1.170	12	.265	-.824	.410
	Universal	-101.77	210.38	58.35	-228.90	25.36	-1.744	12	.107	-1.503	.133
AGF1	Min	70.77	124.36	34.49	-4.38	145.92	2.052	12	.063	-1.887	.059
	Max	-133.00	208.43	57.81	-258.96	-7.04	-2.301	12	.040	-2.271	.023
	Mean	6.69	94.38	26.18	-50.34	63.72	.256	12	.803	-.035	.972
	Universal	-462.08	1521.61	422.02	-1381.57	457.42	-1.095	12	.295	-.594	.552
AGF2	Min	16.46	61.47	17.05	-20.68	53.61	.966	12	.353	-.909	.363
	Max	-28.15	116.58	32.33	-98.60	42.29	-.871	12	.401	-.664	.507
	Mean	24.85	85.14	23.61	-26.61	76.30	1.052	12	.313	-.699	.485
	Universal	14.54	119.79	33.23	-57.85	86.93	.438	12	.669	-.454	.650

[a] $p < .05$ = significant difference.
[b] Compared to mean micro-level estimate.

9.2.2 Assessment of estimate ranges

Population estimates produced via systematic methodologies were evaluated to eliminate methodologies that produced excessive and thus, ineffectual, ranges from the final population estimate range. Excessive estimate ranges were identified as having a maximum estimate at least 250% higher than the minimum estimate, whilst restricted estimate ranges were identified as having a maximum estimate less than 200% higher than the minimum estimate (Table 9.3).

Regional population density coefficient method (RPDC)

The RPDC method produced excessive population estimate ranges for Site Types 1, 2, 4 and Unknown. This is due to wide ranges in constants for the total number of contemporaneous dwellings per hectare (Type 1: 73-432/ha; Type 2: 67-168/ha; Type 4: 80-246/ha; Unknown: 67-432/ha), combined with wide constant ranges for the number of people per dwelling (Type 1: 1.2-3.7; Type 2: 3.3-4.8; Type 4: 2.7-4.7; Unknown: 1.2-6.6).

Conversely, the constant ranges for Site Types 3 and 5 are relatively constrained (Type 3: 100-122 dwellings/ha; 3.7-5.1 people/dwelling; Type 5: 92 dwellings/ha; 4.8-6.6 people/dwelling), producing more restricted estimate ranges.

Residential built area proportions method (RBAP)

The RBAP method produced excessive estimate ranges for Site Types 1 and Unknown. This reflects the combination of considerable ranges in constants for the proportion of contemporaneous residential built area in site area (Type 1: 29.84-54.57%; Unknown: 17.15-54.57%), the mean residential built area of complete dwellings (Type 1: 7.6-26.3 m^2; Unknown: 7.6-29.5 m^2) and the number of people per dwelling (Type 1: 1.2-3.7; Unknown: 1.2-6.6).

The combination of marginally more restricted constant ranges for Site Types 2 and 5 produced moderately constrained estimate ranges (Type 2: RBAP: 19.02-20.97%, 16-28.2 m^2 mean floor area, 3.3-4.8 people/dwelling; Type 5: 27-47.2 m^2 mean floor area, 4.8-6.6 people/dwelling).

Refined constant ranges for Site Types 3 (RBAP: 17.15-27.83%; 21-29.5 m^2 mean floor area; 3.7-5.1 people/dwelling) and 4 (RBAP: 19.21-32.57%; 15.3-24 m^2 mean floor area; 2.7-4.7 people/dwelling) produced restricted estimate ranges for these site types.

Residential floor area proportions method (RFAP)

As the range of constants for the mean residential floor area per person is restricted for all site types (maximum range: 2.89-4.53 m^2 per person), this variable has limited impact on the final population estimate ranges derived from the RFAP method.

Considerable constant ranges for the proportion of contemporaneous residential floor area in site area for Site Types 1 (14.85-32.13%) and Unknown (11.33-32.13%%) resulted in excessive population estimate ranges for these site types. A marginally more refined constant range for Site Type 4 (12.1-21.33%) produced moderately constrained estimates.

Refined constant ranges for Site Types 2 (14.39-16.58%) and 3 (11.33-16.77%) produced restricted population estimate ranges. For Site Type 5, only a mean constant could be established for the proportion of contemporaneous residential floor area in site area (17.68%). This combined with the limited range in mean residential floor area per person (2.9-4 m^2) also produced restricted population estimate ranges.

Storage provisions formulae (SPF)

For each site type, a hypothesised amount of residential storage provision was suggested based on potential storage within sites assessed at the micro-level. Site Types 3, 4 and 5 were all suggested to contain considerable designated storage space separate from the residential floor area. Therefore, it was hypothesised that the maximum amount of residential storage provision would not occur within these site types. For Site Type 5, the formula reflecting no residential storage provision was also excluded based on micro-level assessment of Basta (the only Type 5 site). For Site Types 1, 2 and Unknown all amounts of storage were considered possible.

For all site types, the SPF produced reasonably constrained population estimate ranges, regardless of variations in the ranges of constants.

Settlement population density coefficient method (SPDC)

For all site types except Unknown, the SPDC method produced restricted population estimate ranges, despite variations in the ranges of density coefficients. For sites of Unknown type, the SPDC range was considerable (322-926 people/ha), producing excessive population estimate ranges. These results support the use of site type, rather than universal, density coefficients.

Naroll's (1962) allometric growth formula (AGF1)

Replacement of Naroll's (1962) original initial growth index with re-calculated indices in the AGF1 produced excessive population estimate ranges for Site Types 1, 4 and Unknown due to considerable ranges in constants for the proportion of built floor area in site area and the re-calculated indices (Type 1: 29.47-53.97%, 8.8-13.4; Type 4: 29.21-61.12%, 21.2-36.1; Unknown: 23.98-61.12%, 8.8-48.1).

More refined constant ranges produced restricted population estimate ranges for Site Types 2, 3 and 5 (Type 2: 23.98-40.01%, 17.9-18.6; Type 3: 36.56-49.67%, 19.7-23.4; Type 5: 36.6-48.1).

Wiessner's (1974) allometric growth formula (AGF2)

For all site types, except Unknown, the range of constants for the AGF2 village index was limited, resulting in restricted population estimate ranges. For sites of Unknown type, the village index range was considerable (11.4-31.5), producing excessive population estimate ranges. These results support the use of site type, rather than universal, village initial growth indices for Wiessner's (1974) AGF2.

Methods included in final estimate range

Statistical analysis indicated that three systematic methods produce results that differ significantly from the micro-level estimate: RPDC, AGF1 and RBAP. These methods, in addition to the RFAP method, produced excessive estimate ranges for at least one classified site type (Tables 9.3-9.4). The SPF was the only method that produced estimates that correlated well with the micro-level estimates and produced relatively constrained estimate ranges for all site types, including sites of Unknown type. Based on this analysis, the final estimate ranges for type classed sites are derived from the SPF, SPDC and AGF2, with estimates for sites of Unknown type derived solely from the SPF.

Table 9.3. Examples of estimate ranges for each method.

Method	Range*	Type	Site name	Estimate range	Difference between minimum/ maximum estimate (%)
Regional population density coefficient (RPDC)	Excessive	1	Gesher (PPNA)	13-237	1823
		2	Jericho (PPNA)	565-2021	358
		4	Beisamoun (MPPNB)	1060-5826	550
		Unknown	Nahal Betzet I (MPPNB)	40-1427	3568
	Restricted	3	Beidha (LPPNB)	112-187	167
		5	'Ain Ghazal (LPPNB)	4428-6089	138
Residential built area proportions (RBAP)	Excessive	1	Gesher (PPNA)	38-216	568
		Unknown	Nahal Betzet I (MPPNB)	111-745	671
	Moderate	2	Jericho (PPNA)	622-1437	231
		5	'Ain Ghazal (LPPNB)	3758-9032	240
	Restricted	3	Beidha (LPPNB)	105-125	119
		4	Beisamoun (MPPNB)	1797-2967	165
Residential floor area proportions (RFAP)	Excessive	1	Gesher (PPNA)	60-167	278
		Unknown	Nahal Betzet I (MPPNB)	125-556	445
	Moderate	4	Beisamoun (MPPNB)	1465-3213	219
	Restricted	2	Jericho (PPNA)	795-1238	156
		3	Beidha (LPPNB)	106-170	160
		5	'Ain Ghazal (LPPNB)	4420-6097	138
Storage provisions formulae (SPF)	Moderate	1	Gesher (PPNA)	63-130	206
		2	Jericho (PPNA)	737-1651	224
		Unknown	Nahal Betzet I (MPPNB)	177-374	211
	Restricted	3	Beidha (LPPNB)	104-166	160
		4	Beisamoun (MPPNB)	2133-3396	159
		5	'Ain Ghazal (LPPNB)	4379-6283	144
Settlement population density coefficient (SPDC)	Excessive	Unknown	Nahal Betzet I (MPPNB)	161-463	288
	Restricted	1	Gesher (PPNA)	70-139	199
		2	Jericho (PPNA)	805-1319	164
		3	Beidha (LPPNB)	111-178	160
		4	Beisamoun (MPPNB)	1908-3318	174
		5	'Ain Ghazal (LPPNB)	4380-6040	138
Naroll's (1962) allometric growth formula (AGF1)	Excessive	1	Gesher (PPNA)	61-216	354
		4	Beisamoun (MPPNB)	1251-5642	451
		Unknown	Nahal Betzet I (MPPNB)	46-1047	2276
	Restricted	2	Jericho (PPNA)	956-1832	192
		3	Beidha (LPPNB)	97-171	176
		5	'Ain Ghazal (LPPNB)	4163-5759	138
Wiessner's (1974) village allometric growth formula (AGF2)	Excessive	Unknown	Nahal Betzet I (MPPNB)	159-439	276
	Restricted	1	Gesher (PPNA)	68-132	194
		2	Jericho (PPNA)	795-1238	156
		3	Beidha (LPPNB)	106-170	160
		4	Beisamoun (MPPNB)	1823-3189	175
		5	'Ain Ghazal (LPPNB)	4386-6024	137

* Excessive = maximum estimate > 250% higher than minimum estimate; Moderate = maximum estimate 200-250% higher than minimum estimate; Restricted = maximum estimate < 200% higher than minimum estimate.

Table 9.4. Potential suitability of methods for producing systematic population estimates (most suitable methods highlighted in grey).

Method	**Site type** 1	2	3	4	5	*Unknown*	**Correlates with micro-level estimate**
Regional population density coefficient (RPDC)	**X**	-	✓	-	✓	**X**	**No**
Residential built area proportions (RBAP)	-	-	✓	✓	-	-	**No**
Residential floor area proportions (RFAP)	-	✓	✓	-	✓	-	Yes
Storage provisions formulae (SPF)	✓	✓	✓	✓	✓	✓	Yes
Settlement population density coefficient	✓	✓	✓	✓	✓	-	Yes
Naroll's (1962) allometric growth formula	-	✓	✓	-	✓	**X**	**No**
Wiessner's (1974) allometric growth formula	✓	✓	✓	✓	✓	-	Yes

9.3 Population estimates and group size thresholds per period

Minimum, maximum and mean population size estimates were produced for all sites in the central and southern Levantine PPN village database (Tables 9.5-9.6; Figures 9.8-9.20)[2]. Estimates are provided for each period by site type and are assessed against the previously hypothesised group size thresholds relating to changing subsistence practices; mechanisms for reducing scalar stress and promoting social cohesion; and increasing social complexity. Additional thresholds are proposed based on the population estimates achieved in this investigation and the archaeological evidence available for each site (Appendix E.4). As such, these thresholds are tentative and will require revision as additional information becomes available.

The proposed thresholds consider population size as the main factor contributing to cultural complexity. This is obviously problematic in that it does not consider other factors that influence socio-cultural development (i.e. geographical context or cultural background). However, as the thresholds proposed here are specific to the central and southern Levant during the PPN, these thresholds provide a solid basis for exploring the relationship between group size and other factors impacting socio-cultural evolution in future.

9.3.1 Pre-Pottery Neolithic A

PPNA villages (*n* = 18) were categorised as either Site Type 1: small (< 0.4 ha) or 2: large (≥ 0.4 ha) with predominantly curvilinear architecture. Estimates for Type 1 villages (*n* = 12) range from around 30 people at Nahal Oren (P = 25-45; 0.05 ha) to around 180 people at 'Ein Suhun (P = 130-280; 0.3 ha) (Tables 9.5-9.6; Figures 9.8-

[2] For sites assessed at the micro-level, estimates are based on the micro-level assessment.

9.9). Estimates for Type 2 villages (*n* = 6) range from around 190 people at Dhra' (P = 130-300; 0.45 ha) to around 1,060 people at Jericho (P = 740-1,650; 2.5 ha).

Changing subsistence practices

Estimates for all villages exceed the minimum group size threshold previously hypothesised for the initial transition to a sedentary existence (P ≥ 25) (see Table 4.8 for references for each hypothesised threshold). This threshold is equivalent to the lowest estimate achieved in this investigation (PPNA Nahal Oren: P = 25-45).

Adoption of farming practices is expected to occur in populations of at least 50 people, with transition to agro-pastoralist practices expected to occur in populations of at least 100 people. There is evidence for cultivation of pre-domesticated plants during the PPNA, particularly at Type 2 villages, including Dhra' (P = 130-300), Gilgal I (P = 160-290), Netiv Hagdud (P = 220-270) and Jericho (P = 740-1,650) (Kenyon 1981; Finlayson *et al.* 2003; Bar-Yosef *et al.* 1991; 2010a; 2010b); and Type 1 villages situated within geographical zones where conditions may not have been conducive to the natural growth of food plants, such as at Bir el-Maksur (P = 80-190) and Zahrat adh-Dhra'2 (P = 80-190) (Edwards *et al.* 2004; Kuijt and Finlayson 2009; Malinsky-Buller *et al.* 2013). Based on estimates achieved in this investigation and the available archaeological evidence, a minimum group size of around 80 people may coincide with the adoption of farming practices relating to pre-domesticated plants in this region. However, as these practices do not relate to domesticated species (Nesbitt 2002), thresholds relating to agricultural practices cannot be applied to PPNA settlements. PPNA faunal remains suggest a reliance on hunting and an absence of domesticated animals (Martin and Edwards 2013). Therefore, thresholds relating to pastoral practices (i.e. rearing and management of domesticated animals) also cannot be applied to PPNA settlements.

The location of most of these early settlements in resource rich areas with abundant water availability may have negated the need for plant and animal domestication at this stage, even where larger populations existed. Indeed, many villages are situated within or near the Jordan Valley and other hydrological systems with abundant resources, including the Salibiya Basin (Gilgal I and III-IV, Netiv Hagdud and Jericho) (Kenyon 1981; Noy 1989; Bar-Yosef *et al.* 1991; 2010a; 2010b) and the Sea of Galilee (Gesher, Huzuq Musa and 'Ein Suhun) (Garfinkel and Nadel 1989; Nadel *et al.* 1999; Rosenberg *et al.* 2010). In addition, the majority are located at the borders of two or more ecological zones enabling exploitation of a wide range of naturally occurring resources.

Reducing scalar stress and promoting social cohesion

It has been hypothesised that scalar stress often occurs in populations of at least 150 people. To mitigate the effects of scalar stress, communities can either fission into smaller units or develop mechanisms for creating social cohesion. PPNA villages that produced population estimates comparable to or exceeding this threshold (Gilgal I: P = 160-290; Netiv Hagdud: P = 220-270; Jericho: P = 740-1,650) display evidence for such mechanisms, including sectoring of the community into neighbourhoods; compartmentalisation within dwellings potentially aimed at increasing privacy and reducing the perception of overcrowding; and the addition of dwelling annexes for cooking, workshop activities and storage that enabled dwelling units greater control over their own resources (Kenyon 1981; Bar-Yosef *et al.* 1991; 2010a; 2010b). The larger villages, particularly Jericho, also demonstrate evidence for organised communal activities, including the construction of large communal and possibly defensive structures, as well as formalised ritual activities that would have facilitated social cohesion by creating and promoting a collective cultural conscience. The minimum group size estimates for villages that demonstrate conflict reduction strategies (P = 160) compare well with the pre-existing hypothesised threshold (P ≥ 150). An additional threshold could relate to the introduction of more elaborate mechanisms for social cohesion within settlements of at least 740 people (i.e. Jericho: P = 740-1,650).

Emerging social complexity

More complex social structures are hypothesised to occur within populations of greater than 250 people. Some degree of social differentiation may be inferred where there are intra-site variations in structural forms and types of annexed facilities, as at Gilgal I (P = 160-290) and Netiv Hagdud (P = 220-270) (Bar-Yosef *et al.* 1980; 1991; Bar-Yosef and Gopher 1997; Bar-Yosef *et al.* 2010a; 2010b). This could reflect initial segregation of dwelling units and differential engagement with household-based food and production-related activities that are characteristic of house-based societies (Kuijt and Goring Morris 2002, p.368).

Variable distributions of items of personal adornment (i.e. beads and pendants) made of both local and imported materials may reflect promotion of individual identity or group affiliation (Wright and Garrard 2003, p. 277; Bar-Yosef 2005). These items were increasingly produced during the PPNA, with use of more exotic materials at some sites, including Netiv Hagdud (P = 220-270) and Huzuq Musa (P = 300-660) (Bar-Yosef *et al.* 1991; Groman-Yaroslavski *et al.* 2014).

Incised pebbles may be another indicator of the desire for individual identity and could be evidence of transactions between individuals or groups (Edwards and House 2007). These have been uncovered at Zahrat adh-Dhra'2 (P = 80-190), 'Ein Suhun (P = 130-280), Gilgal I (P = 160-290) and Netiv Hagdud (P = 220-270) (Bar-Yosef *et al.* 1991; Nadel *et al.* 1999; Edwards 2007; Edwards and House 2007; Bar-Yosef *et al.* 2010a; 2010b). Similarly, ritual and symbolic items, including figurines at Gilgal IV (P = 40-90), el-Hemmeh (P = 70-100), Zahrat adh-Dhra'2 (P = 80-190), Gilgal I (P = 160-290), Netiv Hagdud (P = 220-270) and Dhra' (P = 130-300) (Kuijt and Chesson 2005) have also been interpreted as tools for individual and group identity. If these aspects do indeed infer social complexity, these developments appear to occur in much smaller groups ($P \geq 40$) than previously suggested. The presence of these developments at such low estimated population sizes could reflect cumulative cultural evolution (White 1959; Castro and Toro 2014) or may be indicative of the broader social networks that existed between sites in close proximity that probably acted together as a larger interconnected regional population (i.e. Gilgal I, III, IV, Netiv Hagdud and Jericho in the Salibiya Basin; and sites adjacent to the Sea of Galilee: Gesher, Huzuq Musa and 'Ein Suhun) (Shennan 2001; Henrich 2004; Vaesen 2012).

The emergence of hierarchical society, including individuals with authoritative roles, is hypothesised to occur in populations of at least 500 people. The best potential evidence for some form of managerial role during the PPNA is the construction of the tower and village wall at Jericho (P = 740-1,650) (Kenyon 1956; 1981). This would have required an organised labour force and careful planning and management. It could also be argued that authoritative individuals may have facilitated the well-established exchange networks that occurred during this period. This may have been the case particularly at Netiv Hagdud (P = 220-270), which has been interpreted as a secondary station for obsidian distribution (Bar-Yosef *et al.* 1991). It must be noted, however, that exchange networks had existed for thousands of years without any clear evidence for authoritative individuals.

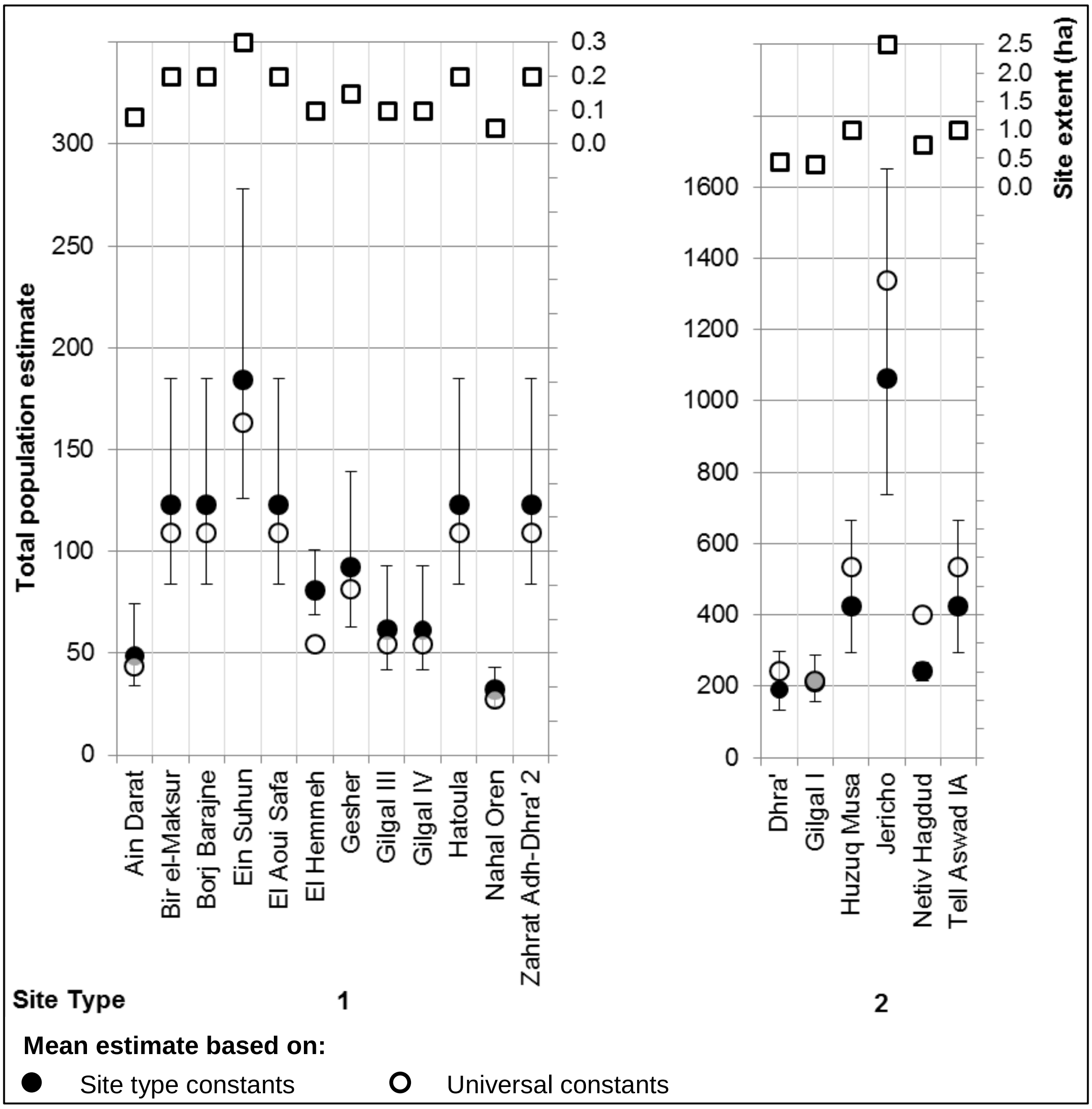


Figure 9.8. PPNA population estimates. Error bars show minimum to maximum range of estimates based on site type constants.

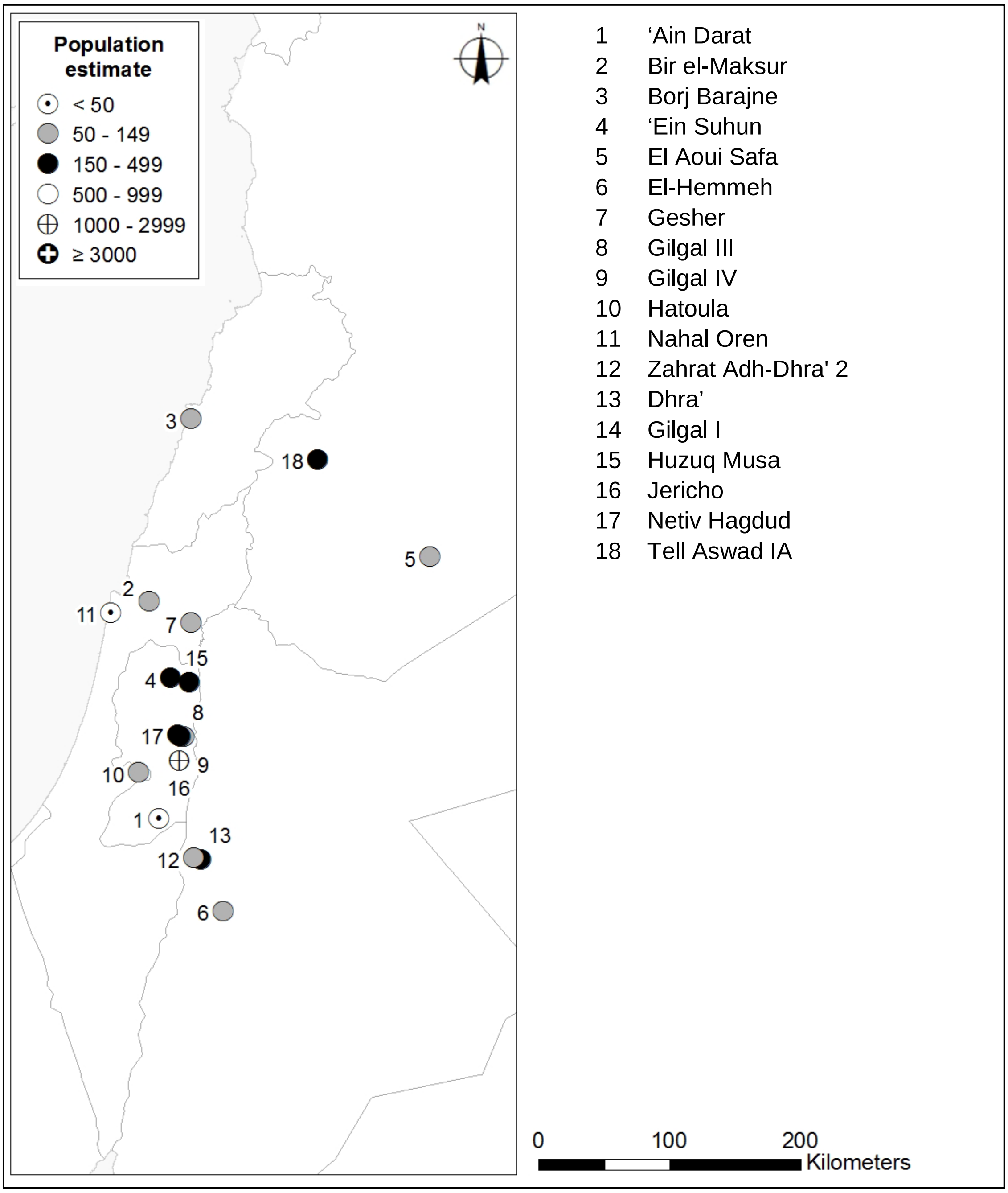


Figure 9.9. Distribution of PPNA villages in the current database indicating population size.

9.3.2 Early Pre-Pottery Neolithic B

EPPNB villages (*n* = 9) were categorised as Site Type 1: small (< 0.4 ha) and 2: large (≥ 0.4 ha) with predominantly curvilinear architecture; and 4: large (0.6-6 ha) with rectilinear architecture. An additional site is of Unknown type. Estimates for Type 1 villages (*n* = 3) range from around 80 people at el-Hemmeh (P = 70-100; 0.1 ha) to around 180 people at 'Ein Suhun (P = 130-280; 0.3 ha) (Tables 9.5-9.6; Figures 9.10-9.11). Estimates for Type 2 villages (*n* = 3) range from around 210 people at Motza VI and Mujahiya (P = 150-330; 0.5 ha) to around 430 people at Tell Aswad IB (P = 300-660; 1 ha). Type 4 villages at Horvat Galil and Tell Qarassa were both estimated at around 520 people (P = 370-680; 1 ha). The village of Unknown type, Mishmar Ha'emeq, was estimated at around 550 people (P = 320-750; 1 ha).

Changing subsistence practices

Archaeological evidence for EPPNB villages is similar to PPNA villages, suggesting continuity in subsistence practices. There is, however, evidence for intensified cultivation of wild plants, particularly at Mujahiya (P = 150-330) (Gopher 1990), which contained high frequencies of sickle blades, and grinding and pounding implements. Tell Aswad IB (P = 300-660) provides the earliest potential evidence for domesticated forms of emmer and barley (Tanno and Willcox 2012; Chamel 2014). The population estimate achieved for Tell Aswad IB falls within the previously hypothesised group size threshold range proposed for the adoption of a fully agro-pastoralist subsistence strategy (P = 100-750). It appears that this may be an appropriate group size threshold for inferring the earliest transition to agriculture within EPPNB communities. However, faunal evidence indicates an absence of domesticated animals and a reliance on hunting, mainly of gazelle, boar, goat and cattle (Gopher 1990; Khalaily *et al.* 2007; Ibañez *et al.* 2010; Bocquentin *et al.* 2011). Therefore, thresholds relating to pastoral practices cannot be applied to the EPPNB.

Reducing scalar stress and promoting social cohesion

Population estimates for all but one EPPNB village (el-Hemmeh: P = 70-100) exceed thresholds at which scalar stress is hypothesised to begin to impact relationships (P ≥ 150). Potential attempts to promote social cohesion are evident in all EPPNB villages, with intensified and more intricate and formalised ritual practices, including the construction of a large, ritual building associated with burial ground at Mishmar Ha'emeq (P = 320-750) (Bocquentin *et al.* 2011). Additional evidence may include the use of yellow and red ochre in ritual contexts at Mujahiya (P = 150-330) (Gopher 1990) and more formalised mortuary practices, including primary and secondary burials, individual and collective burials, skull removal, sub-floor and courtyard burials, and grave goods (i.e. figurines, beads and pendants) at el-Hemmeh (P = 70-100), Motza VI (P = 150-330), Tell Aswad IB (P = 300-660), Mishmar Ha'emeq (P = 320-750), Horvat Galil (P = 370-680) and Tell Qarassa (P = 370-680) (Hershkovitz and Gopher 1988; Khalaily *et al.* 2007; Stordeur and Khawam 2008; Ibañez *et al.* 2010; Bocquentin *et al.* 2011; Makarewicz and Rose 2011; Chamel 2014). These standardised and more formalised ritual activities may have promoted social cohesion by encouraging group ideology.

Innovative architectural developments may reflect a desire to reduce the perception and impact of social crowding. The transition to rectilinear architecture enabled more effective and efficient use of interior space, allowing easier compartmentalisation and more restricted access to interior spaces, increasing privacy and segregation of dwelling units (Flannery 1972; 2002; Wiessner 1982; Saidel 1993). Rectilinear architecture occurs at Horvat Galil (P = 370-680), Tell Qarassa (P = 370-680) and Mishmar Ha'emeq (P = 320-750) (Hershkovitz and Gopher 1988; Ibañez *et al.* 2010; Bocquentin *et al.* 2011). Based on the estimates produced in this investigation and the available archaeological evidence, a possible additional threshold of 320 people may be proposed for the transition to rectilinear architecture during the EPPNB.

Emerging social complexity

Evidence for increasingly independent dwelling units provide some of the earliest potential indication of social complexity (expected to occur at P ≥ 250). Sub-floor burials are considered to represent permanent links between dwelling occupants, the dwelling structure and their ancestors (Watkins 1992). As such, the prevalence of these burials during the EPPNB has been interpreted as reflecting increasing segregation of dwelling units and a general shift towards house-based societies (Kuijt and Goring-Morris 2002). These house units controlled their own production and distribution, providing some of the earliest potential evidence for household economy. At Motza VI (P = 150-330) and Mujahiya (P = 150-330) there is evidence for dwelling-based specialist activities, including the systematic production of beads, pendants and high-quality stone tools (Gopher 1990; Khalaily *et al.* 2007). The rising independence of dwelling units may reflect increasing divergence from egalitarian social systems.

Other aspects of social complexity may be evidenced even within the smallest EPPNB village (el-Hemmeh: P = 70-100). Potential evidence includes enhanced specialist activities and innovative manufacturing techniques, including naviform core technology and lime plaster production, which required a considerable degree of heat and material preparation. Lime plaster is increasingly utilised, particularly in architecture at el-Hemmeh (P = 70-100), Motza VI (P = 150-330), Mujahiya (P = 150-330) and Horvat Galil (P = 370-680) (Hershkovitz and Gopher 1988; Gopher 1990; Khalaily *et al.* 2007; Makarewicz and Rose 2011). These innovative developments required specialist knowledge and may indicate some degree of skill diversification or labour differentiation in communities as small as 70 people.

Other potential evidence for increasingly complex communities during the EPPNB includes differential displays of wealth, including variable association of burials with structures and grave goods at Motza VI (P = 150-330) and Tell Qarassa (P = 370-680) (Khalaily *et al.* 2007; Ibañez *et al.* 2010); and the placement of some bodies on platforms at Tell Aswad IB (P = 300-660) (Stordeur and Khawam 2008; Chamel 2014). The presence of items made from imported materials at el-Hemmeh (P = 70-100), Motza VI (P = 150-330), Mujahiya (P = 150-330) and Tell Qarassa (P = 370-680) (Gopher 1990; Khalaily *et al.* 2007; Ibañez *et al.* 2010; Makarewicz and Rose 2011) indicates a degree of surplus required for trade, potentially requiring individuals with authoritative, decision-making powers to control the acquisition and distribution of these resources (expected to occur at P ≥ 500). These individuals may have been identified via mud tokens, such as those found at Tell Qarassa (P = 370-680), which are argued to reflect formalised means of communication or identification (Edwards 2007; Ibañez *et al.* 2010). In addition, the practice of platform burials at Tell Aswad IB (P = 300-660) may have been reserved for individuals who held a higher status (Stordeur and Khawam 2008; Chamel 2014). The potential occurrence of these developments at lower population sizes could reflect cumulative cultural evolution and/or the considerable interactions between settlements.

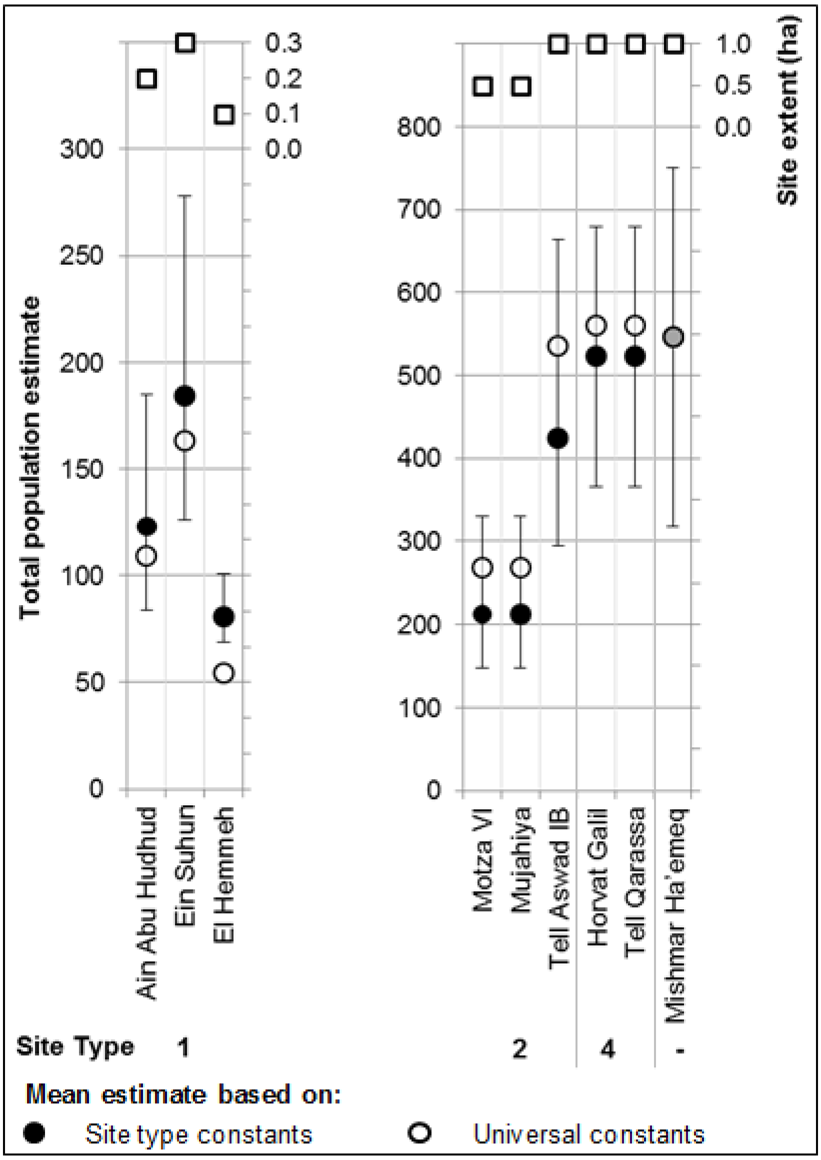


Figure 9.10. EPPNB population estimates. Error bars show minimum to maximum range of estimates based on site type constants.

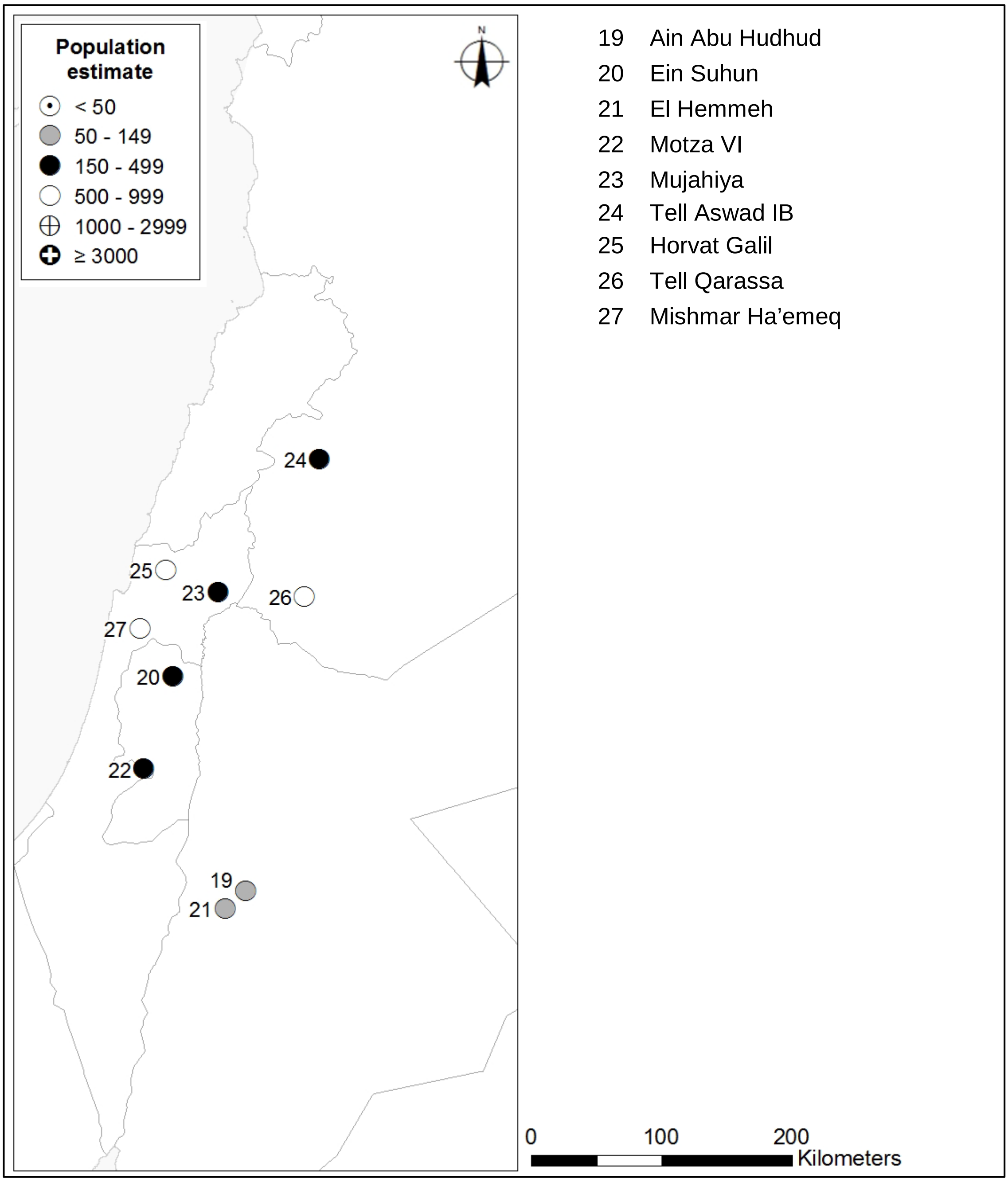


Figure 9.11. Distribution of EPPNB villages in the current database indicating population size.

9.3.3 Middle Pre-Pottery Neolithic B

MPPNB villages (*n* = 28) were categorised as Site Type 1: small (< 0.4 ha) and 2: large (≥ 0.4 ha) villages with predominantly curvilinear architecture; 3: small (≤ 0.5 ha) and 4: large (0.6-6 ha) villages with predominantly rectilinear architecture. An additional four sites are of Unknown type (these produced similar estimates to Type 3 villages). Estimates for Type 1 villages (*n* = 8) range from around 40 people at Jebel Rabigh (P = 30-60; 0.06 ha) to around 120 people at Adh-Dhaman I and Jebel Arqa (P = 80-190; 0.2 ha) (Tables 9.5-9.6; Figures 9.12-9.13). The single Type 2 village at Tell Eli IV, also known as Khirbet Sheikh ‘Ali, was estimated at around 850 people (P = 590-1,320; 2 ha). The two Type 3 villages at Abu Gosh and Wadi Hamarash I were estimated at around 110 people (P = 90-150; 0.25 ha) and 190 people (P = 150-220; 0.5 ha), respectively. Estimates for Type 4 villages (*n* = 13) range from around 510 people at Ghwair I (P = 400-610; 1.33 ha) to around 2,620 people at Beisamoun and Tell Aswad II (P = 1,820-3,400; 5 ha).

Changing subsistence practices

The majority of MPPNB villages, including the smaller settlements (Beidha: P = 80-120; Shkārat Msaied: P = 80-150; ‘Ain Abu Nekheileh: P = 90-150; Wadi Hamarash I: P = 150-220), demonstrate evidence for cultivation of domesticated plants, such as emmer, barley and einkorn (Henry *et al.* 2002; 2003; Henry and Albert 2004; Byrd 2005a; Gkotsinas and Karathanou 2013; Kinzel 2013). Larger villages, such as Yiftah’el IV (P = 370-680), ‘Ain Ghazal (P = 1,460-2,720), Jericho (P = 1,460-2,720) and Tell Aswad II (P = 1,820-3,400), exhibit a wide range of domesticated plants, including barley, einkorn, emmer, lentil, chickpea and flax (Colledge and Conolly 2007; Weiss and Zohary 2011), with the latter also containing evidence for fig cultivation (Stordeur and Jamous 2009). The widespread existence of domesticated plants during the MPPNB, even in villages with small populations, could indicate diffusion of agricultural knowledge from more populated and developed areas to the north, which had adopted agricultural practices during the EPPNB, rather than in situ adaptation by central and southern Levantine villagers. This theory may be supported by the results of a recent analysis of ancient DNA, which revealed that the first famers of the Levant trace around a third of their ancestry to early Anatolian farmers (Lazaridis *et al.* 2016, p.3).

The first clear evidence for pastoral practices relating to domesticated animals occurs during the MPPNB, although many villages still relied on hunting to supplement their diet (Khalaily *et al.* 2007; Barzilai and Getzov 2008). In the smaller MPPNB villages, evidence exists for cultural management of wild animals, such as goats at Beidha (P =

80-120) and Abu Gosh (P = 90-150) (Byrd 2005a; Martin and Edwards 2013), and potential domestication of goats and sheep at Shkārat Msaied (P = 80-150), ‘Ain Abu Nekheileh (P = 90-150) and Wadi Hamarash I (P = 150-220) (Henry *et al.* 2002; 2003; Henry and Albert 2004; Gkotsinas and Karathanou 2013; Kinzel 2013). Domesticated goats were identified at larger villages, such as Ghwair I (P = 400-610) (Simmons and Najjar 2006), whilst domesticated sheep may also have been identified at Tell Ghoraifé I (P = 1,090-2,040) and Wadi Shu’eib (P = 1,090-2,040) (Van Zeist and Bakker-Heeres 1985; Simmons *et al.* 2001). Both domesticated goats and sheep are present at ‘Ain Ghazal (P = 1,460-2,720) and Tell Aswad II (P = 1,820-3,400) (Rollefson *et al.* 1993; Stordeur and Jamous 2009; Martin and Edwards 2013), with both containing evidence for the use of animals for meat and milk production (Makarewicz 2013). Tell Aswad II (P = 1,820-3,400) also produced evidence for domesticated pig earlier in the MPPNB sequence and domesticated cattle later in the MPPNB sequence (Helmer and Gourichon 2008).

Based on the estimates achieved in this investigation and the available archaeological evidence for agricultural and pastoral practices, the previously hypothesised group size threshold for the full transition to an agro-pastoralist subsistence strategy (P = 100-750) may be applicable to MPPNB villages, with additional thresholds of at least 370 people suggested for intensified agricultural activities relating to a wider repertoire of plants; and 1,500 people for intensified pastoral practices relating to a wider selection of animals and productive outputs.

Reducing scalar stress and promoting social cohesion

The majority of MPPNB villages exceed thresholds at which strategies are employed to reduce scalar stress and promote social cohesion (P ≥ 150). Neighbourhoods or distinct clusters of dwellings, separated by open areas, non-residential structures, corridors and/or streets are evident at Beidha (P = 80-120), Shkārat Msaied (P = 80-150), Wadi Hamarash I (P = 150-220), Ghwair I (P = 400-610) and Jericho (P = 1,460-2,720) (Kenyon 1981; Simmons and Najjar 2006; Byrd 2005a; Kinzel 2013; Sampson 2013a). The establishment of clearly defined sectors coincide with evidence for increasing household independence and the emergence of households as economic sub-units (Kuijt and Goring-Morris 2002). Suggested evidence for this is the more formalised and restricted access to dwellings; more ordered interior dwelling space, including greater compartmentalisation to separate areas for specific tasks; and evidence for dwelling based food- and production-related activities. In addition, innovative building techniques enabled the construction of two-storey buildings, such as those at Wadi Hamarash I (P = 150-220) and Ghwair I (P = 400-610) (Simmons and

Najjar 2006; Sampson 2013a), with the former also containing sub-floor channels for water or air ventilation. These contained well-defined areas for living, storage and other activities.

It is suggested that formalised ritual practices may represent another strategy for promoting social cohesion. During the MPPNB, ritual practices intensify and there is remarkable similarity throughout the region, indicating a broad cultural horizon maintained by extensive interactive networks. Typical mortuary practices include primary and secondary burials, skull removal, skull plastering, placement of burials beneath residential floors and association of burials with grave goods (Kuijt and Goring-Morris 2002, pp.394-396). Even within the smaller MPPNB villages, there is evidence for highly formalised ritual practices and symbolic items, including clay anthropomorphic figurines at Beidha (P = 80-120) and Munhata IV-VI (P = 60-150) (Perrot 1966; Byrd 2005a); and large, centrally-located and well-constructed structures, often associated with well-defined open spaces, public staircases, monumental features and burials, such as those identified at Beidha (P = 80-120), Shkārat Msaied (P = 80-150), Wadi Hamarash I (P = 150-220), Mishmar Ha'emeq (P = 160-370), Ghwair I (P = 400-610) and Jericho (P = 1,460-2,720) (Kenyon 1981; Byrd 2005a; Simmons and Najjar 2006; Bocquentin *et al.* 2011; Kinzel 2013; Sampson 2013a).

At Shkārat Msaied (P = 80-150), potential household based ritual activity is evidenced by the regular location of stone cists within dwellings, whilst formalised means of ritual communication are evidenced by numerous incised stone slabs found within ritual contexts (Kinzel 2013). The largest sites at 'Ain Ghazal (P = 1,460-2,720), Jericho (P = 1,460-2,720) and Tell Aswad II (P = 1,820-3,400) (Kenyon 1981; Rollefson *et al.* 1993; Stordeur 2003) provide the most elaborate ritual evidence for this period, with an extensive collection of plastered skulls, and anthropomorphic and zoomorphic figurines comparable to those found in the northern Levant (Kuijt and Chesson 2005). It appears that all MPPNB villages demonstrate mechanisms for social cohesion in the form of intra-village sectoring and ritual activities. However, based on the estimates achieved in this investigation and the available ritual evidence, an additional threshold of around 1,500 people could be suggested for the adoption of highly elaborate ritual practices during this period.

Emerging social complexity

The MPPNB was a period of intensified production, which may reflect the development of skilled occupations and increasing social differentiation. Workshops for the production of beads and other items of personal adornment (Wright and Garrard 2003,

p. 277; Bar-Yosef 2005) occur even within smaller villages, as at Shkārat Msaied (P = 80-150) and Wadi Hamarash I (P = 150-220) (Kinzel 2013; Sampson 2013b). In the more arid southern region, a close network of Type 1 villages appears to have been established at Jebel Arqa (P = 80-190), Jebel Rabigh (P = 30-60), Jebel Ragref (P = 60-140) and Jebel Salaqa (P = 40-90) specifically for large scale production of amazonite beads for export (Berna 1995; Fabiano *et al.* 2004). Items made of obsidian, mother of pearl and ornamental shell, even in these extreme southern regions, indicate well-established trade networks extending through to the northern Levant, which would have enabled at least some people to acquire rare and exotic items. Clay tokens and incised stones found at Shkārat Msaied (P = 80-150), Wadi Hamarash I (P = 150-220) and Ghwair I (P = 400-610) (Simmons and Najjar 2006; Kinzel 2013; Sampson 2013b) may have been utilised within these transactions, or could have been used to identify specific individuals or groups (Edwards 2007).

MPPNB people continued to refine naviform core technology to systematically produce high quality stone tools in workshops at Wadi Hamarash I (P = 150-220) and Yiftah'el IV (P = 370-680) (Barzilai and Getzov 2008; Sampson 2013b); and produced large quantities of lime plaster for floor and wall coatings, skull plastering and the manufacture of figurines. Although plaster was widely used during the MPPNB, few sites, including Yiftah'el IV (P = 370-680) and the mortuary site of Kfar HaHoresh demonstrate evidence for limestone production (Goring-Morris *et al.* 1998; Barzilai and Getzov 2008). These specialist techniques may indicate labour diversification, and potentially reflect an increasingly complex social structure in which individuals, households and the community could enhance skills, wealth and status. As a result, the MPPNB provides the first substantial evidence for a potentially socially and economically stratified community, which could certainly have included authority figures with decision-making powers (P ≥ 500) and potentially rival authority figures (P ≥ 1,500). These figures may have arisen from the need to disseminate specialist knowledge relating to food acquisition, storage and production, manufacturing processes and ritual activities or from the need to control resources acquisition and distribution (Kenyon 1981; Simmons and Najjar 2006; Bocquentin *et al.* 2011; Sampson 2013b). Clay tokens and incised stones could represent means of formal identification of these individuals (Edwards 2007). Based on this analysis, it appears that some degree of social complexity may have occurred within all MPPNB villages, regardless of population size.

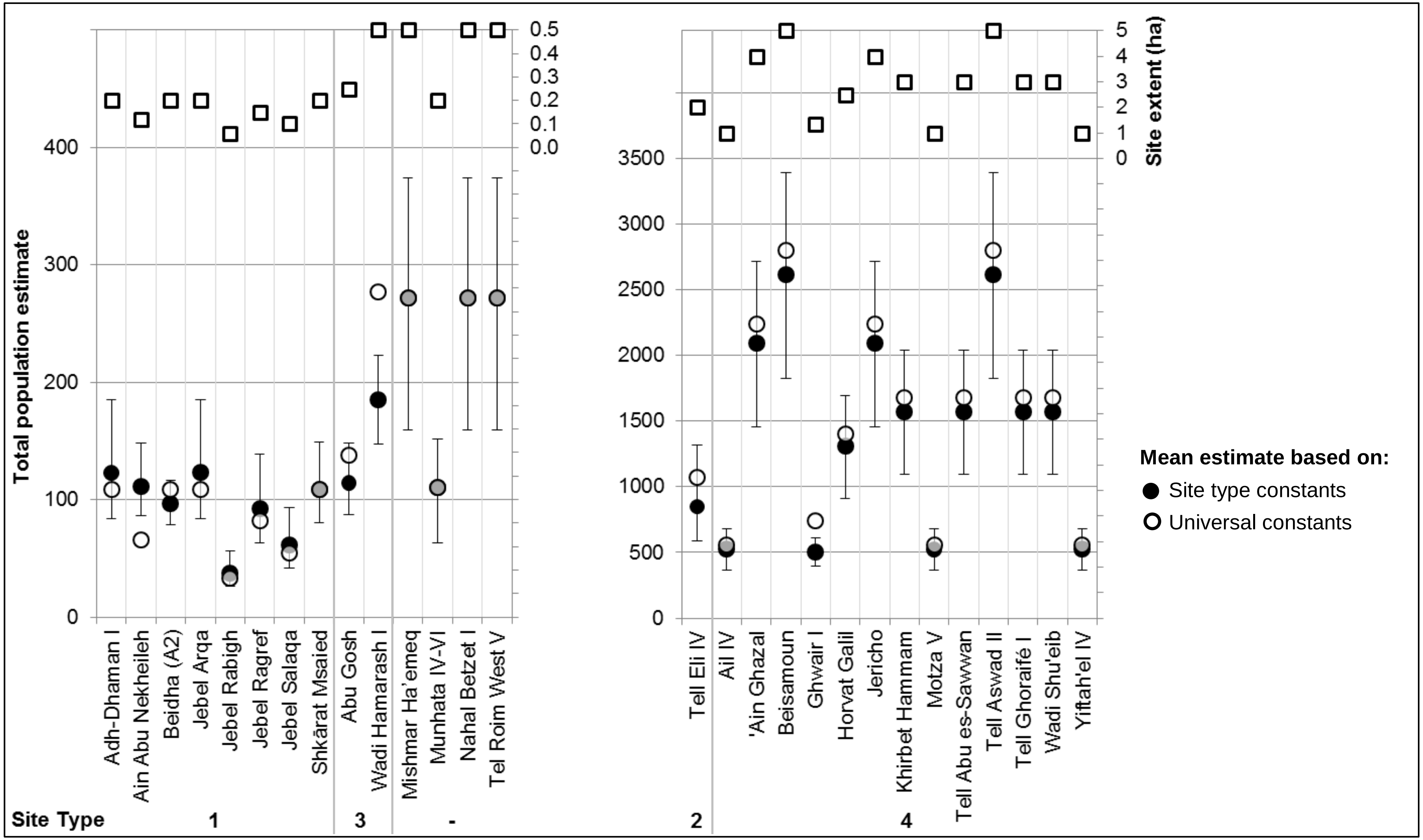


Figure 9.12. MPPNB population estimates. Error bars show minimum to maximum range of estimates based on site type constants.

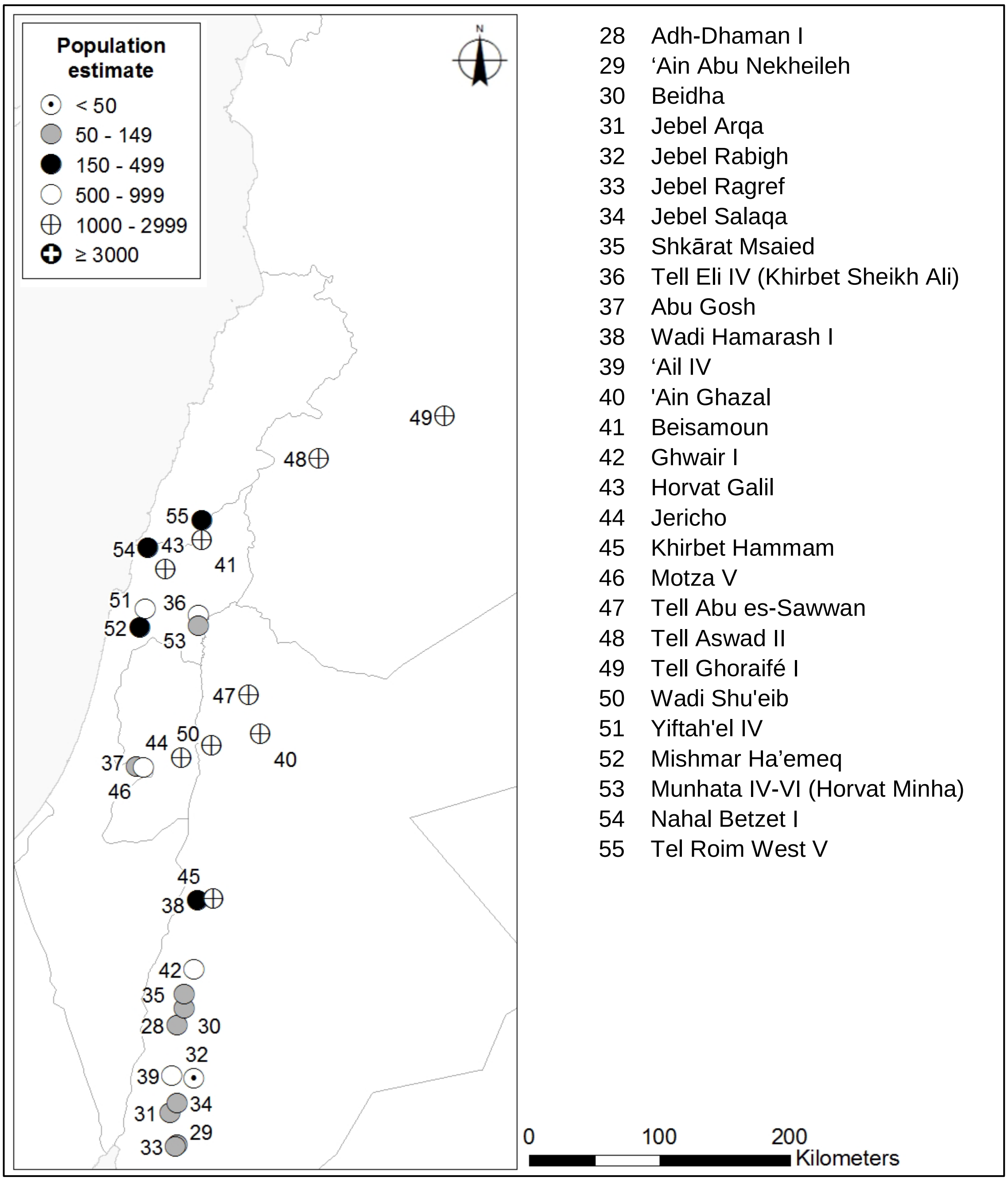


Figure 9.13. Distribution of MPPNB villages in the current database indicating population size.

9.3.4 Late Pre-Pottery Neolithic B

LPPNB villages (*n* = 32) were categorised as Site Type 3: small (≤ 0.5 ha), 4: large (> 0.6-6 ha) and 5: very large (≥ 7 ha) with rectilinear architecture. An additional two sites are of Unknown type (these produced similar estimates to Type 4 villages). Beidha Subphase C2 (0.3 ha) was the only Type 3 village identified for the LPPNB and was estimated at around 180 people (P = 140-220) (Tables 9.5-9.6; Figures 9.14-9.15). Estimates for Type 4 villages (*n* = 18) range from around 520 people at Tell Rakan I and Wadi Badda (P = 370-680; 1 ha) to around 2,620 people at Tell Aray, Tell Eli III, Tell Ghoraifé I, Tell Labwé and Tell Ras Shamra V C (P = 1,820-3,400; 5 ha). Type 5 villages ("mega-sites") first occur during the LPPNB. Estimates range from around 3,640 people at 'Ain Jamam and Khirbet Hammam (P = 3,070-4,400; 7 ha) to around 8,330 people at the combined site of Tell 'Ain el-Kerkh and Tell el-Kerkh II (P = 7,010-10,050; 16 ha).

Changing subsistence practices

The smallest LPPNB village (Beidha: P = 140-220) displays evidence for an agro-pastoralist subsistence strategy involving domesticated barley and emmer, and domesticated goats, although inhabitants still relied heavily on hunting activities to supplement their diet (Byrd 2005a; Martin and Edwards 2013). All other villages produced mean population estimates comparable to or greater than the upper end of the size threshold proposed for the full transition to an agro-pastoralist subsistence strategy (P = 750). These villages demonstrate evidence for a predominantly agro-pastoralist subsistence strategy involving intensive cultivation of wild and domesticated plants, such as barley, emmer, chickpea, lentil and flax (Colledge and Conolly 2007; Weiss and Zohary 2011); and pastoral practices relating to domesticated goats and sheep (Martin and Edwards 2013). Evidence exists for possible cattle domestication at some of the larger sites, as at Tel Tif'dan (P = 1,090-2,040), Tell Labwé (P = 1,820-3,400) and Basta (P = 5,690-7,850) (Martin and Edwards 2013). At several sites, including el-Hemmeh (P = 530-800), Tel Tif'dan (P = 1,090-2,040), Tell Ras Shamra V C (P = 1,820-3,400), 'Ain Jamam (P = 3,070-4,400), es-Sifiya (P = 3,500-5,030) and 'Ain Ghazal (P = 4,380-6,280) evidence exists for the use of animals for meat and milk production (Makarewicz 2009; 2013). An assessment of population sizes produced in this investigation and the archaeological evidence for agricultural and pastoral practices during the LPPNB indicates that the previously hypothesised group size threshold relating to the transition to a fully agro-pastoralist subsistence strategy (P = 100-750) may be suitable for inferring such developments within LPPNB villages, with villages of population sizes comparable to or exceeding the upper limit considered to rely predominantly on agro-pastoralist subsistence strategies.

Reducing scalar stress and promoting social cohesion

Mechanisms for promoting social cohesion within LPPNB villages include the continuation and elaboration of ritual and symbolic practices, which promoted a sense of community, created a collective cultural conscience and enhanced territorial ties. This is evidenced by large ritual buildings and other non-residential structures associated with open and communal areas within the majority of sites, such as Beidha (P = 140-220), Ba'ja (P = 580-610), el-Hemmeh (P = 530-800), Yiftah'el III (P = 550-1,020), Motza Tahtit (P = 730-1,360) and 'Ain Ghazal (P = 4,380-6,280) (Rollefson 1998a; Byrd 2005a; Barzilai and Getzov 2008; Kinzel 2013; White 2013; Mizrahi 2015). Distinctive circular ritual structures have also been uncovered at 'Ain Ghazal and Beidha (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Byrd 2005a).

Typical LPPNB mortuary practices included both primary and secondary burials, individual and collective burials, association of burials with residential structures and grave goods, and a persistence of skull removal in the central Levant. More elaborate practices involved unique grave goods (i.e. a fox mandible at Motza Tahtit: P = 730-1,360) (Lazaridis *et al.* 2016); the insertion of infant bones into wall niches at Tel Tif'dan (P = 1,090-2,040) (Bennallack 2012); the ritual decoration of walls with red paint at Ba'ja (P = 580-610), Yiftah'el III (P = 550-1,020), Tell Labwé (P = 1,820-3,400) and 'Ain Ghazal (P = 4,380-6,280) (Rollefson and Kafafi 1997; Barzilai and Getzov 2008; Ibañez *et al.* 2012; Kinzel 2013); more frequent geometric objects; and highly detailed anthropomorphic and zoomorphic figurines, including a white quartz crystal human figurine with incised red ochre eyes, neck and head uncovered at es-Sifiya (P = 3,500-5,030) and a similar example from Ba'ja (P = 580-610) (Mahasneh 1996, p.140; Kuijt and Chesson 2005). The widespread distribution of these standardised and highly formalised ritual practices and symbolic items, indicates a broad cultural horizon supported by large interactive networks of settlements with similar ideologies and cultural practices. This high degree of regional cohesiveness may be reflected in the general lack of evidence for inter-village conflict despite the rapid regional population growth and expansion that had occurred since the MPPNB (Kuijt and Goring-Morris 2002).

Another method for promoting cohesion within larger populations is via intra-village fissioning or sectoring into neighbourhoods and household units. These strategies allow people to more easily monitor each other, ensuring that each community member fulfils their responsibilities (Dunbar 1992). Neighbourhoods are indicated by clusters of dwellings, separated by open areas, corridors, streets and non-residential structures at the majority of villages, including Beidha (P = 140-220), Ba'ja (P = 580-610), Beisamoun (P = 5,910-8,480) and Basta (P = 5,690-7,850) (Hermansen and Gebel 1996; Byrd 2005a; Nissen 2006; Bocquentin *et al.* 2011; Kinzel 2013). As all LPPNB villages exceed the previously hypothesised threshold at which mechanisms are introduced for social cohesion (P ≥ 150), this threshold could be applied to infer such developments during this period. Based on the population estimates achieved in this investigation and the available archaeological evidence, an additional threshold of around 500 people may coincide with the intensification and elaboration of ritual practices during the LPPNB.

Emerging social complexity

Households appear to form the main socio-economic unit during the LPPNB (Banning 2003). Dwelling form, access and interiors became increasingly systematised, enabling higher density construction and larger dwelling occupant numbers. Dwelling unit size estimates achieved for LPPNB Type 3 (3.9-6.4 people) and 5 (4.7-8.4 people) villages in this investigation indicate that dwellings within these sites may have been inhabited by large nuclear or extended families (Table 9.6). These dwellings contained evidence for dwelling and/or household based production-related activities, and a considerable amount of storage, indicating a high degree of household control of resources and production. Dwelling based workshops have been uncovered at several sites, including those for large-scale sandstone ring production at Ba'ja (P = 580-610) (Kinzel 2013); bead production at Beidha (P = 140-220) (Byrd 2005a), el-Hemmeh (P = 530-800) (White 2013), Tel Tif'dan (P = 1,090-2,040) (Bennallack 2012), 'Ain Jamam (P = 3,070-4,400) (Makarewicz 2009) and al-Baseet (P = 3,290-4,710) (Fino 1997); and wood-working at es-Sifiya (P = 3,500-5,030) (Mahasneh and Gebel 1998). The presence of household based industry suggests hereditary specialist knowledge and could support interpretations of a shift in economic focus towards house-based societies (Gebel 2002; Gillespie 2007). However, Baird *et al.* (2016) argue that these household economic units probably formed an important part of an overarching supra-household economic group.

The promotion of individual and household economic interests, a high degree of skills specialisation and elaborate ritual practices are all considered evidence of an increasingly complex social structure (P ≥ 250), potentially including authoritative figures with decision-making powers (P ≥ 500). Population estimates for all LPPNB villages, except Beidha (P = 140-220), which also demonstrates these characteristics, exceed the previously hypothesised group size thresholds for these developments. The potential presence of these characteristics within all LPPNB villages probably reflects cumulative culture, as well as the extensive interactive networks that had existed in the region for several centuries. Many villages (i.e. Ba'ja; Jebels Arqa, Ragref, Rabigh and Salaqa, etc.) appear to have focussed on a limited number of economic activities and it was through these broader networks that they would have been able to acquire additional necessary and luxury resources.

There appears to have been massive population expansion during the LPPNB, reflecting large-scale population aggregation within very large Type 5 villages ("mega-sites") (P > 3,000). It is suggested that rival authoritative figures may have arisen within populations greater than 1,500 people, potentially producing politically stratified communities. This may be evidenced by clearly defined and distinct habitation zones within some settlements (i.e. Ba'ja, Basta and Beisamoun). However, deducing such developments from the available archaeological evidence is problematic and requires further research.

It is hypothesised that innovative methods aimed at improving sustainability and living conditions would be introduced within populations of at least 3,000 people. LPPNB innovations relating to water management included barrage construction at Wadi Badda (P = 370-680) (Fujii 2007), and possible intentional irrigation at Ba'ja (P = 580-610) (Kinzel 2013) and el-Hemmeh (P = 530-800) (White 2013). It appears that innovative methods occurred within smaller populations (P ≥ 370). This could further reflect cumulative culture and/or the close ties that existed between LPPNB communities, providing additional impetus for assessing the aggregate populations of clusters of settlements rather than individual village populations.

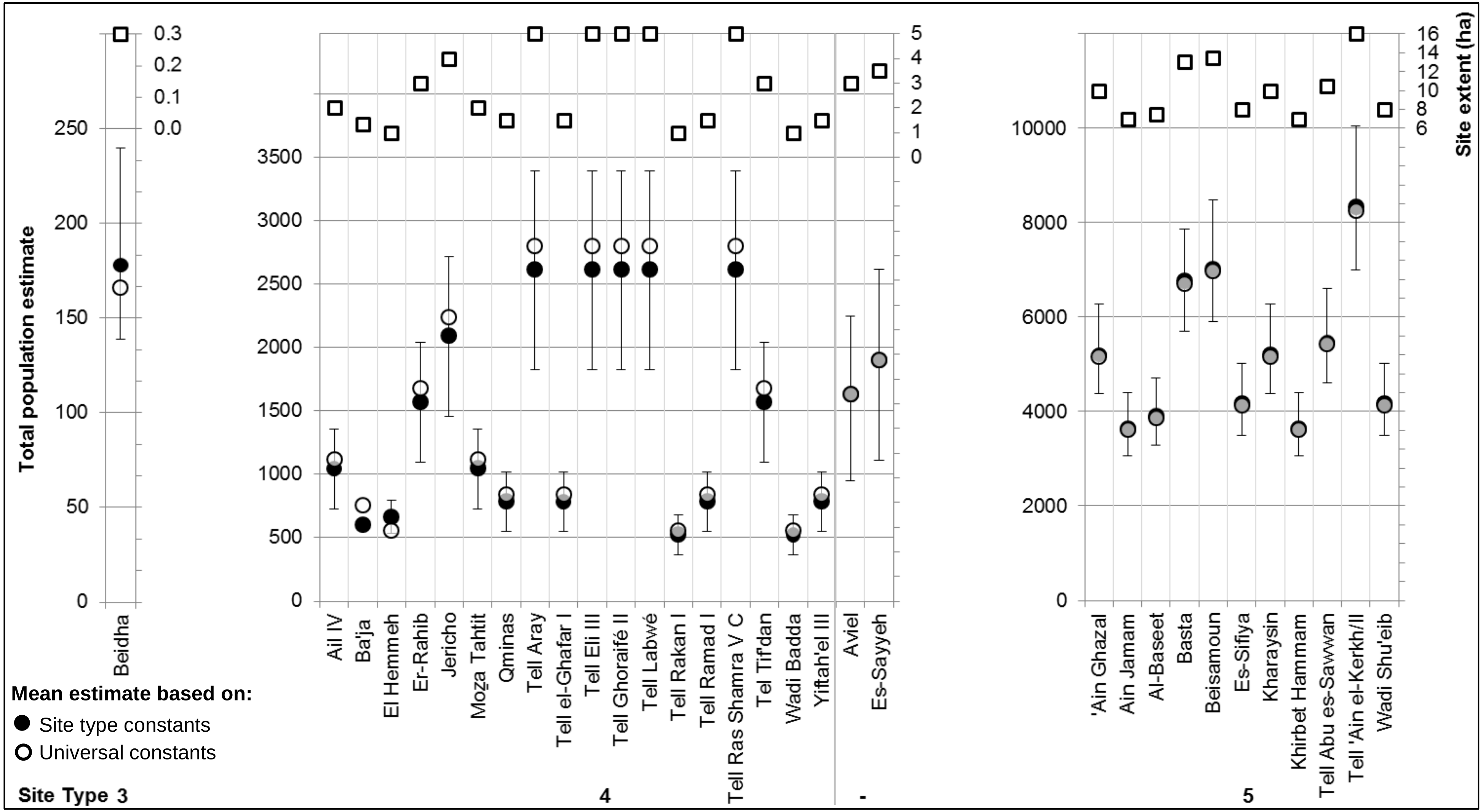


Figure 9.14. LPPNB population estimates. Error bars show minimum to maximum range of estimates based on site type constants.

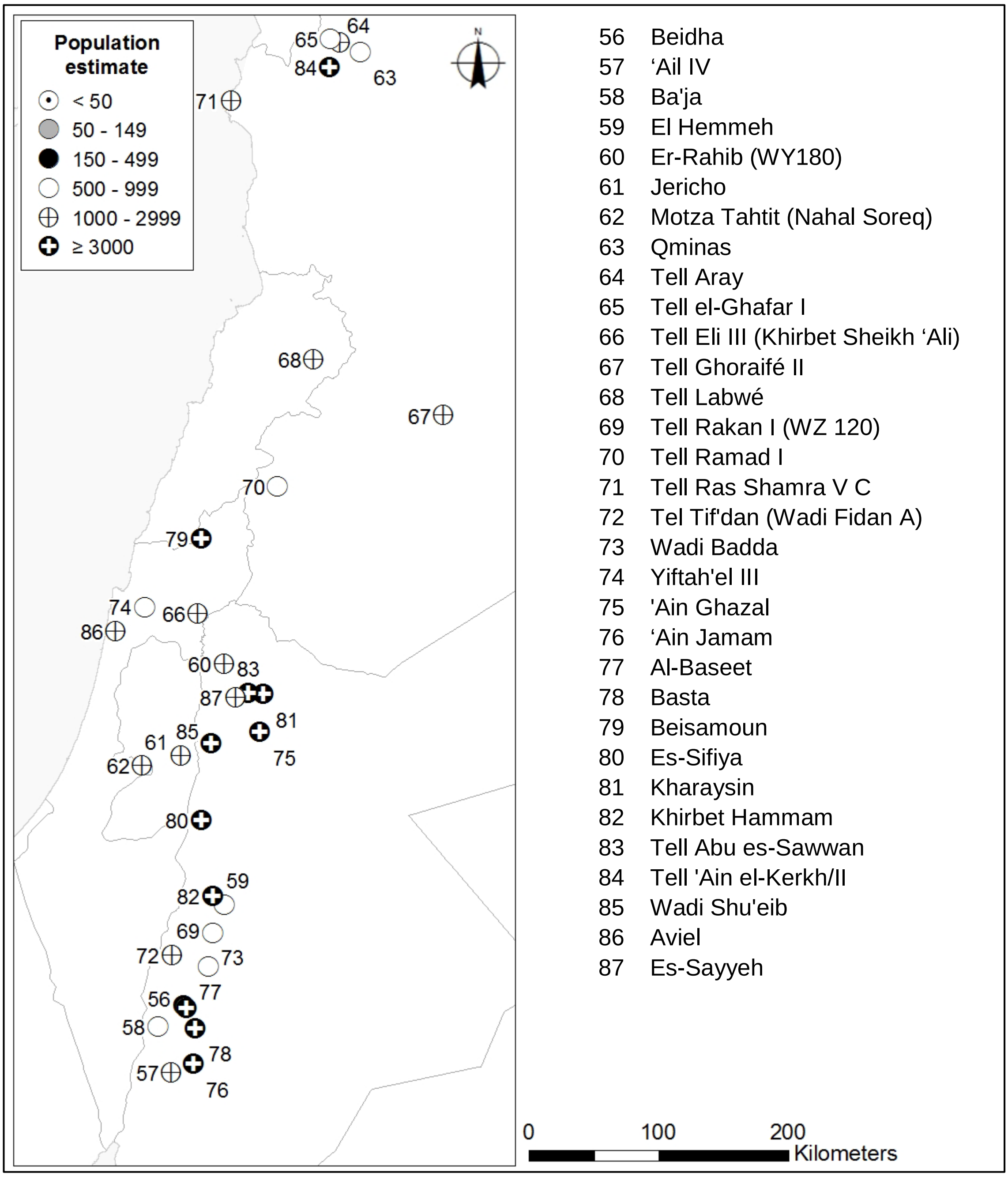


Figure 9.15. Distribution of LPPNB villages in the current database indicating population size.

9.3.5 Pre-Pottery Neolithic C

PPNC villages (*n* = 19) were categorised as Site Type 4: large (0.6-6 ha) and 5: very large (≥ 7 ha) villages with rectilinear architecture. An additional two sites are of Unknown type (these produced similar estimates to Type 4 villages). Estimates for Type 4 villages (*n* = 14) range from around 520 people at Tell Roim West IV (P = 370-680; 1 ha) to around 3,140 people at Tell 'Ain el-Kerkh/Tell el-Kerkh II and Wadi Shu'eib (P = 2,190-4,080; 6 ha) (Tables 9.5-9.6; Figures 9.16-9.17). Estimates for Type 5 villages (*n* = 3) range from around 3,640 people at Basta (7 ha) and Beisamoun (P = 3,070-4,400; 7 ha) to around 4,170 people at 'Ain Ghazal (P = 3,500-5,030; 8 ha[3]).

Changing subsistence practices

By the PPNC, archaeological evidence suggests that most central and southern Levantine villages were predominantly reliant on an agro-pastoralist subsistence strategy (Colledge and Conolly 2007; Weiss and Zohary 2011; Makarewicz 2013; Martin and Edwards 2013). A wide variety of domesticated plant forms, including emmer, barley, naked wheat, einkorn, cereals, lentils, flax and legumes have been identified at Wadi Fidan C (P = 480-1,120), Tell Ramad II (P = 950-1,770), Atlit-Yam (P = 1,090-2,040) and Tell Labwé (P = 1,280-2,380) (Galili *et al.* 2004; Colledge and Conolly 2007; Weiss and Zohary 2011; Ibañez *et al.* 2012).

Use of domesticated goats and sheep for meat and milk production were common (Makarewicz 2009; 2013). High frequencies of cattle bones indicate intensive hunting or pastoral practices relating to cattle at several sites, including Atlit-Yam (P = 1,090-2,040), Tell Labwé (P = 1,280-2,380) and Tell Teo (P = 1,280-2,380) (Galili *et al.* 2004; Bocquentin *et al.* 2011; Ibañez *et al.* 2012). Similarly high frequencies of pig bones have been identified at Atlit-Yam (P = 1,090-2,040), Hagoshrim VI (P = 1,280-2,380) and 'Ain Ghazal (P = 3,500-5,030) (Wasse 2002; Galili *et al.* 2004; Haber and Dayan 2004). The coastal inhabitants of Atlit-Yam (P = 1,090-2,040) also exploited large quantities of fish and may have kept domesticated dogs and cats (Galili *et al.* 2004). Estimates for all PPNC villages are within or exceed the previously hypothesised group size threshold for adoption of a fully agro-pastoralist subsistence strategy (P = 100-750), indicating that this may be a suitable threshold for inferring this development with PPNC villages. Additional thresholds of around 500 people for intensified agricultural

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[3] A site extent of 12 hectares is proposed for PPNC 'Ain Ghazal (Rollefson *et al.* 1992, p.446). However, given the prolonged population demands on local resources, evidence for increased aridity, and evidence for decreased population density, including a reduction in expenditure on construction and maintenance of domestic architecture and greater allocation of space for domesticated animals, a reduced site extent of eight hectares is utilised in this investigation (Kuijt and Goring-Morris 2002, pp.414-415; Zielhofer *et al.* 2012, p.439).

practices and around 1,000 people for intensified pastoral practices could be applied to the PPNC.

Reducing scalar stress and promoting social cohesion

Evidence for mechanisms to promote social cohesion in the PPNC is similar to that suggested for the LPPNB. This includes standardise and highly formalised ritual and mortuary practices, such as primary and secondary burials, individual and group burials, association of burials with residential structures, wall decoration, grave goods and anthropomorphic and zoomorphic figurines (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Galili *et al.* 2004; Kuijt and Chesson 2005; Barzilai and Getzov 2008; Ibañez *et al.* 2012). Distinctive circular ritual structures appear at Atlit-Yam (P = 1,090-2,040) (Galili *et al.* 2004), similar to those of LPPNB 'Ain Ghazal and Beidha (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Byrd 2005a).

Household socio-economic units appear to be well-established by the PPNC. This is reflected by the multi-storey structures with formalised layout, restricted dwelling access and evidence for dwelling based food-related and economic activities. The designation of space for specific activities and the sustained distinction between public and private space would have mitigated some of the effects of social crowding within these densely packed settlements (Banning 2003). More substantial evidence for community segmentation beyond the household level occurs at Atlit-Yam (P = 1,090-2,040) and 'Ain Ghazal (P = 3,500-5,030), where long walls dissect the settlements (Goring-Morris and Belfer-Cohen 2008).

Estimates for all PPNC villages exceed the previously hypothesised group size threshold for the introduction of mechanisms for promoting social cohesion (P ≥ 150). An additional threshold of around 1,000 people could be suggested for inferring more substantial attempts at community segmentation.

Emerging social complexity

All PPNC villages included in this investigation have population estimates that exceed previously hypothesised thresholds for increasingly complex social structures (P ≥ 250) and the presence of individuals or groups with authoritative, decision-making powers (P ≥ 500). This could explain the widespread presence of labour intensive agro-pastoralist practices, which required relatively large and organised populations (Fletcher 1981; Kuijt and Goring-Morris 2002).

Increasingly specialised techniques for manufacturing stone tools and items of personal adornment (i.e. beads, bracelets, pendants and buttons) from stone, bone, shell and mother of pearl, may reflect labour differentiation, with such items potentially acting as identity markers for specific individuals and/or groups (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Simmons *et al.* 2001; Wright and Garrard 2003, p. 277; Galili *et al.* 2004; Bar-Yosef 2005; Barzilai and Getzov 2008; Bocquentin *et al.* 2011; Nadel and Nadler-Uziel 2011; Ibañez *et al.* 2012).

The construction of water wells at Atlit-Yam (P = 1,090-2,040) (Galili *et al.* 2004) required specialist hydrological knowledge and an organised work force, possibly suggesting some form of managerial role. A recent discovery of a megalithic installation at Atlit-Yam has provided further evidence for large-scale, organised communal activity (Eshed and Galili 2011, p.409) (Figure 9.18). The maintenance of extensive trade networks and creative developments, such as game boards (Rollefson *et al.* 1993; Rollefson and Kafafi 1997), indicate production surplus and time for leisure activities, which are usually associated with prosperous communities. However, this prosperity was probably not equally distributed, as is evidenced by differential displays of wealth, particularly in burial contexts (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Galili *et al.* 2004; Kuijt and Chesson 2005; Barzilai and Getzov 2008; Ibañez *et al.* 2012). This evidence for social inequality could provide support for the interpretation of these sites as increasingly stratified and hierarchical. As for the LPPNB, rival authority figures may even have occurred within the largest settlements (P ≥ 1,500). This may be evidenced by long-running walls that effectively dissected settlements into distinct sectors, as at Atlit-Yam (P = 1,090-2,040) and ‘Ain Ghazal (P = 3,500-5,030) (Goring-Morris and Belfer-Cohen 2008).

An assessment of PPNC village population estimates produced in this investigation and the available archaeological evidence indicates that previously hypothesised thresholds relating to social complexity (P ≥ 250) and the rise of authoritative figures (P ≥ 500) may be suitable for inferring such processes within PPNC communities. An additional threshold of around 1,000 people could be suggested for inferring innovative developments requiring highly specialist hydrological knowledge (i.e. well construction).

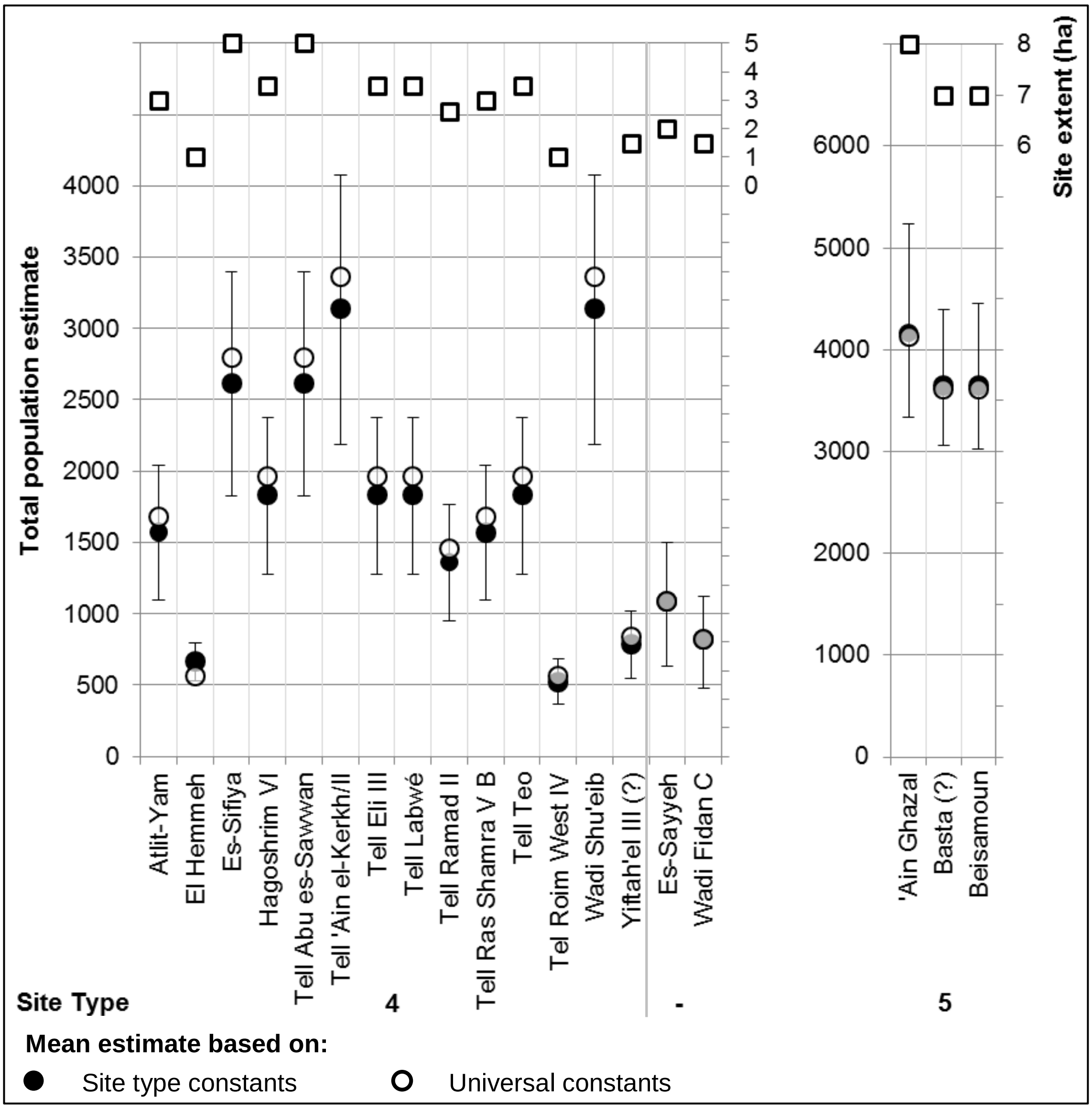

Figure 9.16. PPNC population estimates. Error bars show minimum to maximum range of estimates based on site type constants.

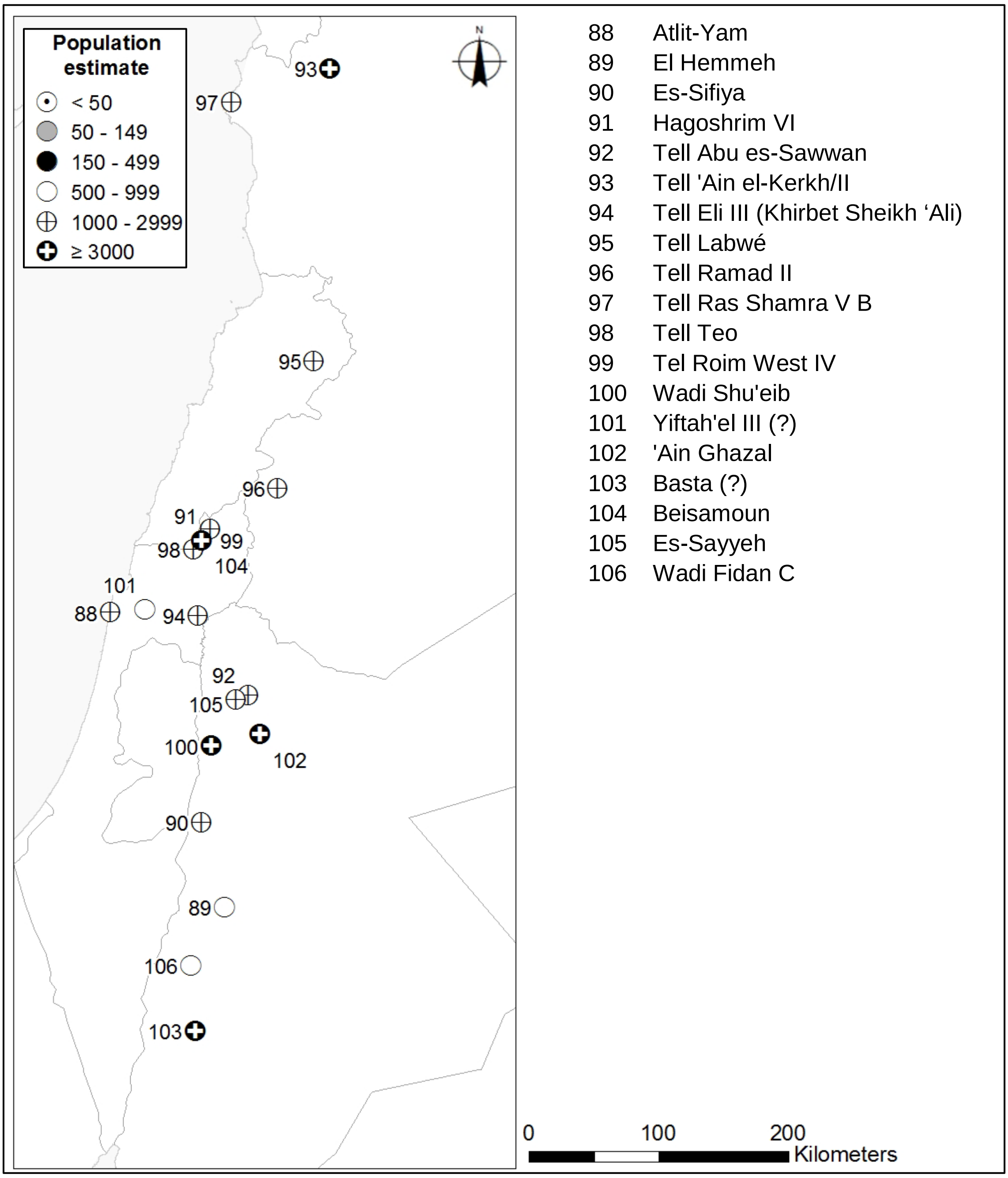

Figure 9.17. Distribution of PPNC villages in the current database indicating population size.


Figure 9.18. Megalithic installation at PPNC Atlit-Yam (Eshed and Galili 2011, p.409).

Table 9.5. Population and density estimates for central and southern Levantine PPN villages.

Period	ID	Site name	Site type	Site extent (ha)	Final (adult) population estimates *Min*	*Max*	***Mean***	People per dwelling (SPF2)	RADC (m^2 residential floor area/person)	SPDC (people/ha)
PPNA	1	'Ain Darat	1	0.08	34	74	**49**	2.4	3.62	608
	2	Bir el-Maksur	1	0.20	84	185	**123**	2.4	3.58	615
	3	Borj Barajne	1	0.20	84	185	**123**	2.4	3.58	615
	4	Ein Suhun	1	0.30	126	278	**184**	2.4	3.58	614
	5	El Aoui Safa	1	0.20	84	185	**123**	2.4	3.58	615
	6	El Hemmeh	1	0.10	69	101	**81**	1.2	2.79	846
	7	Gesher	1	0.15	63	139	**92**	2.4	3.59	613
	8	Gilgal III	1	0.10	42	93	**61**	2.4	3.59	613
	9	Gilgal IV	1	0.10	42	93	**61**	2.4	3.59	613
	10	Hatoula	1	0.20	84	185	**123**	2.4	3.58	615
	11	Nahal Oren	1	0.05	24	43	**32**	2.8	3.64	675
	12	Zahrat Adh-Dhra' 2	1	0.20	84	185	**123**	2.4	3.58	615
	13	Dhra'	2	0.45	133	298	**191**	4.7	3.65	424
	14	Gilgal I	2	0.40	157	287	**211**	3.5	3.27	555
	15	Huzuq Musa	2	1.00	295	664	**425**	4.7	3.64	425
	16	Jericho	2	2.50	737	1651	**1062**	4.7	3.65	425
	17	Netiv Hagdud	2	0.75	215	268	**241**	4.8	4.53	322
	18	Tell Aswad IA	2	1.00	295	664	**425**	4.7	3.64	425
EPPNB	19	'Ain Abu Hudhud	1	0.20	84	185	**123**	2.4	3.58	615
	20	Ein Suhun	1	0.30	126	278	**184**	2.4	3.58	614
	21	El Hemmeh	1	0.10	69	101	**81**	1.2	2.79	846
	22	Motza VI	2	0.50	148	330	**212**	4.7	3.65	425
	23	Mujahiya	2	0.50	148	330	**212**	4.7	3.65	425
	24	Tell Aswad IB	2	1.00	295	664	**425**	4.7	3.64	425
	25	Horvat Galil	4	1.00	365	679	**523**	3.8	3.29	523
	26	Tell Qarassa	4	1.00	365	679	**523**	3.8	3.29	523
	27	Mishmar Ha'emeq	-	1.00	317	751	**546**	3.5	3.41	546
MPPNB	28	Adh-Dhaman I	1	0.20	84	185	**123**	2.4	3.58	615
	29	'Ain Abu Nekheileh	1	0.12	86	148	**111**	2.3	3.56	972
	30	Beidha (A2)	1	0.20	79	116	**97**	2.1	3.17	487
	31	Jebel Arqa	1	0.20	84	185	**123**	2.4	3.58	615
	32	Jebel Rabigh	1	0.06	26	56	**37**	2.4	3.57	617
	33	Jebel Ragref	1	0.15	63	139	**92**	2.4	3.59	613
	34	Jebel Salaqa	1	0.10	42	93	**61**	2.4	3.59	613
	35	Shkārat Msaied	1	0.20	80	149	**109**	3.8	3.58	574
	36	Tell Eli IV	2	2.00	590	1321	**849**	4.7	3.65	425
	37	Abu Gosh	3	0.25	87	148	**114**	4.5	3.08	456
	38	Wadi Hamarash I	3	0.50	147	223	**185**	3.7	3.21	370
	39	'Ail IV	4	1.00	365	679	**523**	3.8	3.29	523
	40	'Ain Ghazal	4	4.00	1459	2717	**2096**	3.8	3.29	524
	41	Beisamoun	4	5.00	1823	3396	**2619**	3.8	3.29	524
	42	Ghwair I	4	1.325	399	612	**506**	4.8	3.32	382
	43	Horvat Galil	4	2.50	912	1698	**1310**	3.8	3.29	524
	44	Jericho	4	4.00	1459	2717	**2096**	3.8	3.29	524
	45	Khirbet Hammam	4	3.00	1094	2037	**1571**	3.8	3.29	524
	46	Motza V	4	1.00	365	679	**523**	3.8	3.29	523
	47	Tell Abu es-Sawwan	4	3.00	1094	2037	**1571**	3.8	3.29	524
	48	Tell Aswad II	4	5.00	1823	3396	**2619**	3.8	3.29	524
	49	Tell Ghoraifé I	4	3.00	1094	2037	**1571**	3.8	3.29	524
	50	Wadi Shu'eib	4	3.00	1094	2037	**1571**	3.8	3.29	524
	51	Yiftah'el IV	4	1.00	365	679	**523**	3.8	3.29	523
	52	Mishmar Ha'emeq	-	0.50	159	374	**272**	3.5	3.42	544
	53	Munhata IV-VI	-	0.20	63	152	**110**	3.5	3.38	550
	54	Nahal Betzet I	-	0.50	159	374	**272**	3.5	3.42	544
	55	Tel Roim West V	-	0.50	159	374	**272**	3.5	3.42	544

Period	ID	Site name	Site type	Site extent (ha)	Final (adult) population estimates Min	Max	Mean	People per dwelling (SPF2)	RADC (m^2 residential floor area/person)	SPDC (people/ha)
LPPNB	56	Beidha (C2)	3	0.30	141	216	**178**	5.2	2.96	594
	57	‘Ail IV	4	2.00	729	1358	**1048**	3.8	3.29	524
	58	Ba'ja	4	1.35	584	610	**603**	3.5	4.13	664
	59	El Hemmeh	4	1.00	532	795	**664**	2.7	3.35	664
	60	Er-Rahib	4	3.00	1094	2037	**1571**	3.8	3.29	524
	61	Jericho	4	4.00	1459	2717	**2096**	3.8	3.29	524
	62	Motza Tahtit	4	2.00	729	1358	**1048**	3.8	3.29	524
	63	Qminas	4	1.50	547	1019	**786**	3.8	3.29	524
	64	Tell Aray	4	5.00	1823	3396	**2619**	3.8	3.29	524
	65	Tell el-Ghafar I	4	1.50	547	1019	**786**	3.8	3.29	524
	66	Tell Eli III	4	5.00	1823	3396	**2619**	3.8	3.29	524
	67	Tell Ghoraifé II	4	5.00	1823	3396	**2619**	3.8	3.29	524
	68	Tell Labwé	4	5.00	1823	3396	**2619**	3.8	3.29	524
	69	Tell Rakan I	4	1.00	365	679	**523**	3.8	3.29	523
	70	Tell Ramad I	4	1.50	547	1019	**786**	3.8	3.29	524
	71	Tell Ras Shamra V C	4	5.00	1823	3396	**2619**	3.8	3.29	524
	72	Tel Tif'dan	4	3.00	1094	2037	**1571**	3.8	3.29	524
	73	Wadi Badda	4	1.00	365	679	**523**	3.8	3.29	523
	74	Yiftah'el III	4	1.50	547	1019	**786**	3.8	3.29	524
	75	'Ain Ghazal	5	10.00	4379	6283	**5206**	6.5	3.40	521
	76	‘Ain Jamam	5	7.00	3066	4397	**3644**	6.5	3.40	521
	77	Al-Baseet	5	7.50	3285	4712	**3904**	6.5	3.40	521
	78	Basta	5	13.00	5693	7854	**6773**	5.7	3.49	521
	79	Beisamoun	5	13.50	5912	8480	**7028**	6.5	3.40	521
	80	Es-Sifiya	5	8.00	3504	5026	**4165**	6.5	3.40	521
	81	Kharaysin	5	10.00	4379	6283	**5206**	6.5	3.40	521
	82	Khirbet Hammam	5	7.00	3066	4397	**3644**	6.5	3.40	521
	83	Tell Abu es-Sawwan	5	10.50	4598	6598	**5466**	6.5	3.40	521
	84	Tell 'Ain el-Kerkh/II	5	16.00	7007	10052	**8329**	6.5	3.40	521
	85	Wadi Shu'eib	5	8.00	3504	5026	**4165**	6.5	3.40	521
	86	Aviel	-	3.00	952	2249	**1635**	3.5	3.41	545
	87	Es-Sayyeh	-	3.50	1111	2621	**1906**	3.5	3.42	545
PPNC	88	Atlit-Yam	4	3.00	1094	2037	**1571**	3.8	3.29	524
	89	El Hemmeh	4	1.00	532	795	**664**	2.7	3.35	664
	90	Es-Sifiya	4	5.00	1823	3396	**2619**	3.8	3.29	524
	91	Hagoshrim VI	4	3.50	1276	2377	**1833**	3.8	3.29	524
	92	Tell Abu es-Sawwan	4	5.00	1823	3396	**2619**	3.8	3.29	524
	93	Tell 'Ain el-Kerkh/II	4	6.00	2188	4075	**3143**	3.8	3.29	524
	94	Tell Eli III	4	3.50	1276	2377	**1833**	3.8	3.29	524
	95	Tell Labwé	4	3.50	1276	2377	**1833**	3.8	3.29	524
	96	Tell Ramad II	4	2.60	948	1766	**1362**	3.8	3.29	524
	97	Tell Ras Shamra V B	4	3.00	1094	2037	**1571**	3.8	3.29	524
	98	Tell Teo	4	3.50	1276	2377	**1833**	3.8	3.29	524
	99	Tel Roim West IV	4	1.00	365	679	**523**	3.8	3.29	523
	100	Wadi Shu'eib	4	6.00	2188	4075	**3143**	3.8	3.29	524
	101	Yiftah'el III (?)	4	1.50	547	1019	**786**	3.8	3.29	524
	102	'Ain Ghazal	5	8.00	3504	5026	**4165**	6.5	3.40	521
	103	Basta (?)	5	7.00	3066	4397	**3644**	6.5	3.40	521
	104	Beisamoun	5	7.00	3066	4397	**3644**	6.5	3.40	521
	105	Es-Sayyeh	-	2.00	635	1498	**1089**	3.5	3.42	545
	106	Wadi Fidan C	-	1.50	476	1123	**817**	3.5	3.42	545

Table 9.6. Population and density estimates per period and site type.

Period	**Site type**	**Number of sites**	**Mean site extent (ha)**	**Final (adult) population estimates**			**People per dwelling**			**RADC (residential floor area/person m²)**			**SPDC (people/ha)**		
				Min	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***
PPNA	All	18	0.44	24	1651	**207**	1.0	8.0	**3.1**	1.60	7.65	**3.59**	286	1006	**569**
	1	12	0.16	24	278	**98**	1.0	4.9	**2.3**	1.60	7.65	**3.52**	420	1006	**638**
	2	6	1.02	133	1651	**426**	2.3	8.0	**4.5**	2.17	5.62	**3.73**	286	717	**429**
EPPNB	All	9	0.62	69	751	**315**	1.0	8.0	**3.5**	1.51	10.14	**3.43**	295	1006	**549**
	1	3	0.20	69	278	**129**	1.0	4.9	**2.0**	1.60	7.65	**3.32**	420	1006	**692**
	2	3	0.67	148	664	**283**	2.8	8.0	**4.7**	2.17	5.62	**3.65**	295	664	**425**
	4	2	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	-	1	1.00	317	751	**546**	1.2	8.0	**3.5**	1.51	10.14	**3.41**	317	751	**546**
MPPNB	All	28	1.52	26	3396	**783**	1.2	8.0	**3.5**	1.49	10.20	**3.38**	294	1231	**543**
	1	8	0.15	26	185	**94**	1.2	4.9	**2.5**	1.59	7.65	**3.53**	395	1231	**638**
	2	1	2.00	590	1321	**849**	2.8	8.0	**4.7**	2.18	5.62	**3.65**	295	661	**425**
	3	2	0.38	87	223	**150**	2.9	6.4	**4.1**	1.91	4.82	**3.14**	294	592	**413**
	4	13	2.83	365	3396	**1469**	2.2	5.8	**3.9**	1.78	5.85	**3.29**	301	679	**513**
	-	4	0.43	63	374	**232**	1.2	8.0	**3.5**	1.49	10.20	**3.41**	315	760	**546**
LPPNB	All	32	5.21	141	10052	**2723**	1.2	8.4	**4.7**	1.51	10.13	**3.35**	317	795	**535**
	3	1	0.30	141	216	**178**	3.9	6.4	**5.2**	2.33	3.58	**2.96**	469	719	**594**
	4	18	2.74	365	3396	**1438**	2.2	5.6	**3.7**	1.78	5.85	**3.34**	365	795	**539**
	5	11	10.05	3066	10052	**5230**	4.7	8.4	**6.4**	2.93	4.04	**3.40**	438	628	**521**
	-	2	3.25	952	2621	**1771**	1.2	8.0	**3.5**	1.51	10.13	**3.42**	317	750	**545**
PPNC	All	19	3.87	365	5026	**2036**	1.2	8.4	**4.1**	1.51	10.13	**3.32**	317	795	**533**
	4	14	3.44	365	4075	**1810**	2.2	5.6	**3.7**	1.78	5.85	**3.29**	365	795	**534**
	5	3	7.33	3066	5026	**3817**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	-	2	1.75	476	1498	**953**	1.2	8.0	**3.5**	1.51	10.13	**3.42**	317	749	**545**

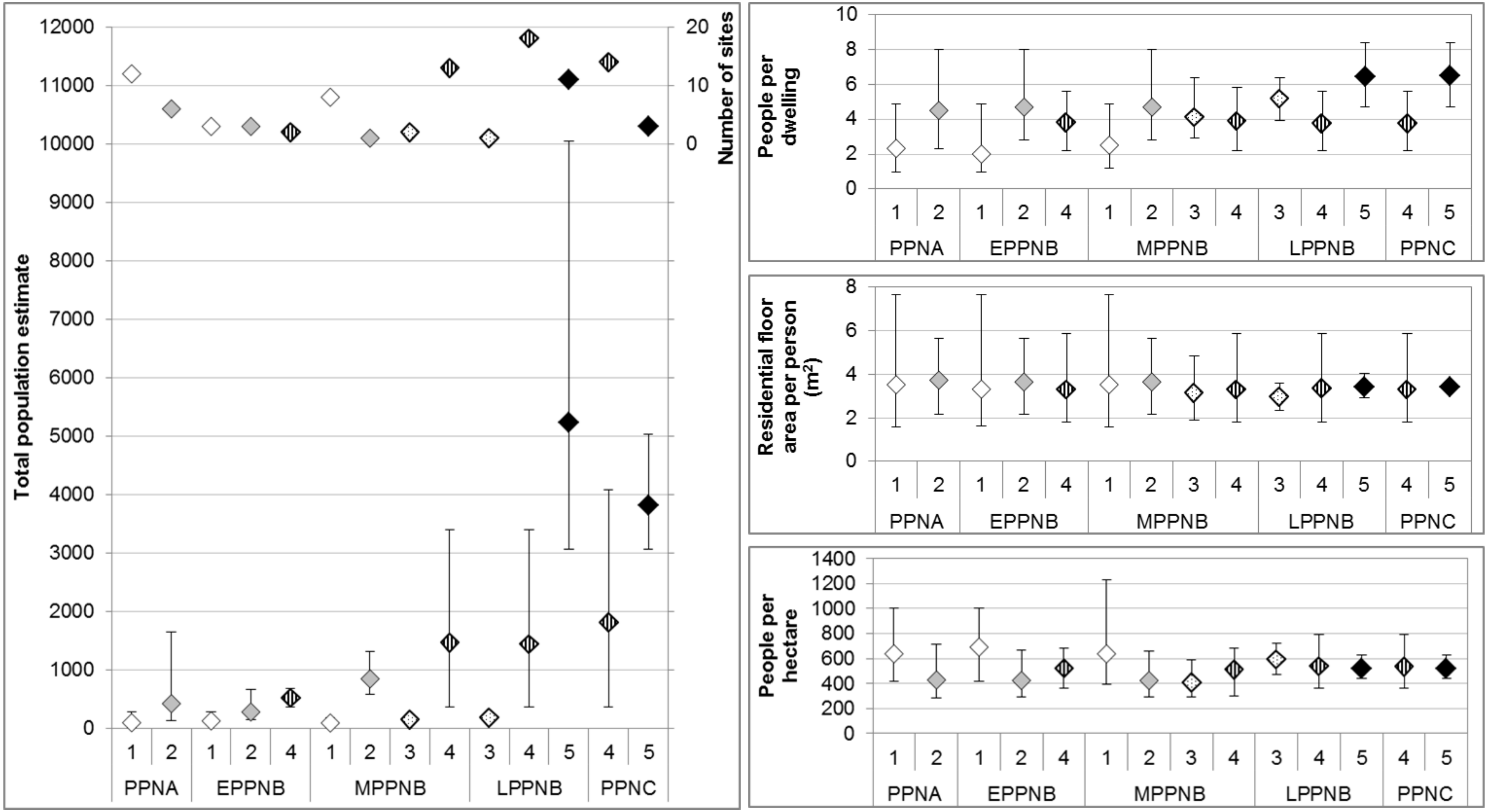

Figure 9.19. Mean population and density estimates per period and site type (1-5). Errors bars display minimum to maximum values.

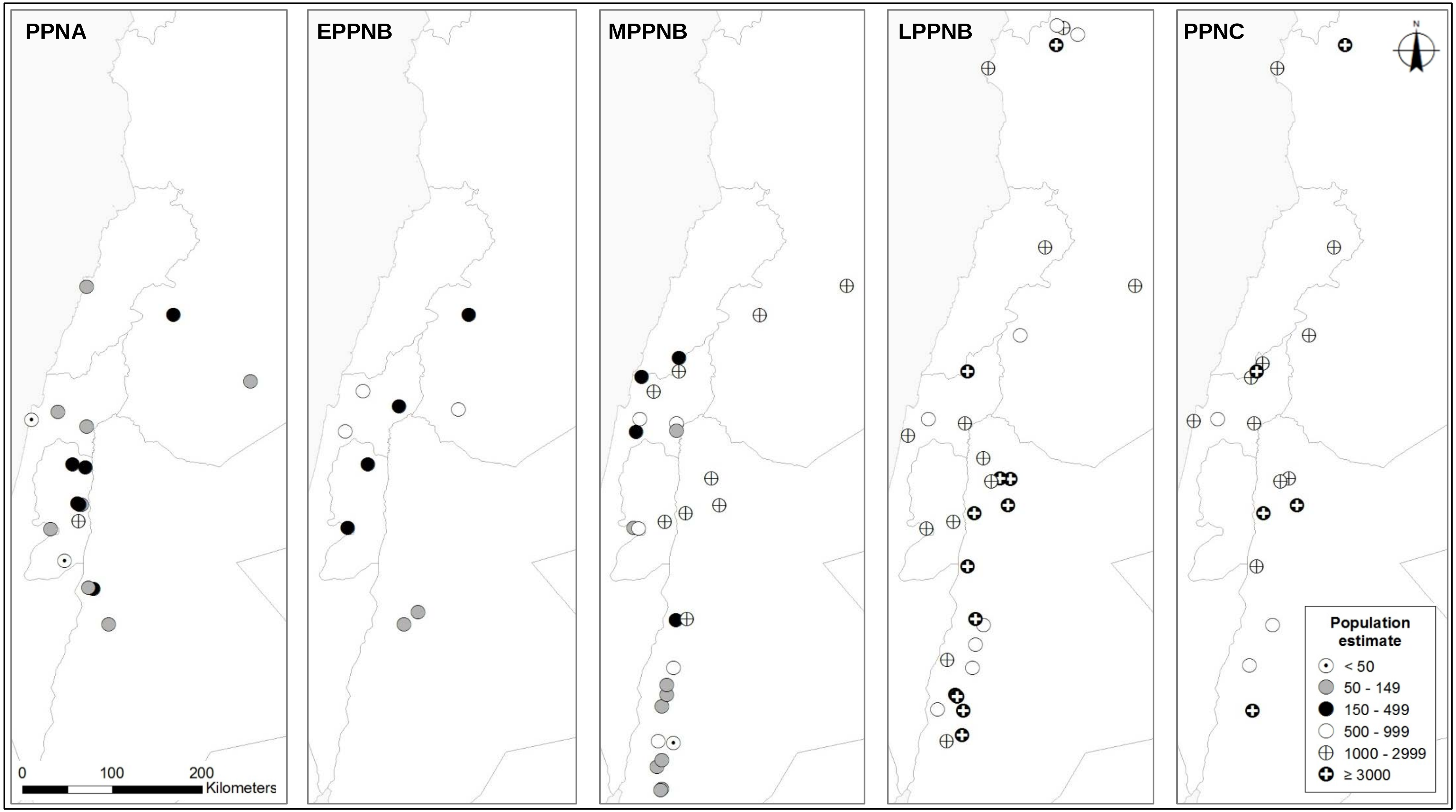

Figure 9.20. Population estimates per period.

9.4 Summary of population density per period and site type

Minimum, maximum and mean density estimates were produced for all sites in the central and southern Levantine village database (Tables 9.5-9.6; Figure 9.19; Appendix E.5). Dwelling unit size estimates are based on the SPF Method 2 (SPF2), which directly calculates dwelling unit size from constants for the mean residential floor area of complete dwellings (m^2). Residential floor area per person (RADC) is derived from estimates of total contemporaneous residential floor area and total population. Population density (SPDC: people/ha) is derived from estimates of total site extent and total population. For sites assessed at the micro-level, estimates are based on the micro-level assessment.

9.4.1 People per dwelling

Dwelling unit size estimates range from around one to 8.4 people, with a mean of 4.3 people (Table 9.6; Figure 9.19). There appears to be a general trend towards larger dwelling unit sizes throughout the PPN. Type 1 villages, which occurred in the earlier PPN periods, produced mean dwelling unit sizes of 2.4 people (range: 1-4.9), suggesting that nuclear families may not have formed the predominant dwelling unit type within all Type 1 villages. This could support the interpretation of some small compounds of circular huts as being inhabited by extended family units in which dwellings were occupied by individuals, pairs or an adult and their offspring (Flannery 1972; Bar-Yosef 1998). However, as dwelling unit sizes are derived from SPF population estimates based on adult occupants only, these unit sizes would be increased following consideration of children.

All other site types recorded dwelling unit sizes that could reflect habitation by nuclear, or perhaps extended, family units. Estimates produced for Type 5 sites (mean: 6.4 people; range: 4.7-8.4 people) could certainly indicate extended family dwelling units. This is consistent with current theory relating to the transition from nuclear to extended family units during the later PPN periods and the notion that extended families may have formed the predominant dwelling unit type within large, rectilinear, highly compartmentalised dwellings typical of later PPN Type 3, 4 and 5 sites (Byrd 1994; Watkins 1990; 1996; Flannery 2002; Rollefson and Kafafi 2013). The almost ubiquitous evidence for household-based production, consumption and storage within these site types further supports this theory.

9.4.2 Residential floor area per person

Estimates of residential floor area per person are relatively consistent throughout the PPN and across all site types (mean range: 3.08-3.7 m^2; total range: 1.59-7.65 m^2), although there appears to be a slight reduction over time (Table 9.6; Figure 9.19). These estimates compare well with those derived for comparable sites in other investigations (2.16-4.55 m^2 per person) (Hill 1970; Clarke 1974; Kramer 1979; Hayden *et al.* 1996) and the range utilised in RADC population estimates in this investigation (1.77-5 m^2). The restricted range provides an opportunity to utilise these values in methodologies for estimating population size in future.

The highest mean space allowance was recorded within villages of predominantly curvilinear architecture (Type 1: 3.5 m^2; Type 2: 3.7 m^2). This may reflect attempts to increase privacy and mitigate the effects of overcrowding within these generally non-compartmentalised structures (Flannery 1972; Brown 1987).

9.4.3 People per hectare

Population density estimates for type classed sites range from around 290 to 1,230 people per hectare (Table 9.6; Figure 9.19). Despite being based on adult population only, almost all density estimates far exceed the density coefficients previously utilised for estimating PPN Levantine village populations (90-294 people/ha) (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008; Campbell 2009).

Mean density values are relatively consistent throughout the PPN, although greater variability in ranges is evident in earlier PPN periods. Type 1 sites recorded the highest densities (mean: 640 people/ha; range: 400-1,230 people/ha). This reflects the high structural density and limited amount of open space within several Type 1 sites assessed at the micro-level (i.e. el-Hemmeh, Nahal Oren, ‘Ain Abu Nekheileh). Population density within Type 2 villages (mean: 430 people/ha; range: 300-660 people/ha) is around 35% lower than Type 1 villages. This is consistent with the theory of allometric growth relating to open circular hut compounds, whereby settlement size increases by the square of population size, resulting in a reduction in population density (Wiessner 1974). Despite higher dwelling unit sizes in Type 2 villages, the population density is considerably lower. This could reflect spatial organisational strategies aimed at reducing social crowding and conflict within these larger settlements. This may be further evidenced by the increasing segregation of household units as indicated by the addition of annexes and sectoring of structures into dwelling clusters or neighbourhoods. This sectoring is evident at Gilgal I (Bar-Yosef *et al.*

2010a; 2010b), Netiv Hagdud (Bar-Yosef *et al.* 1991) and Jericho (Kenyon 1956; 1981).

Type 3 sites recorded low densities (mean: 410 people/ha; range: 290-590 people/ha). This reflects separation between dwelling units and large areas of open and communal space within Type 3 sites assessed at the micro-level (i.e. Wadi Hamarash I, Beidha Subphase C2).

Site Types 4 (mean: 530 people/ha; range: 300-800 people/ha) and 5 (mean: 520 people/ha; range: 440-630 people/ha) recorded comparable densities, reflecting the similarities between the architectural forms and spatial distribution of built and open areas within these settlements.

9.5 Annual population growth rates

Population growth rates were derived from total period length (see calibrated BC date ranges in Table 3.1) and estimates of total population per period (Table 9.7; Figure 9.21). As site detection rates are unknown, the total population estimates cannot be considered estimates of village meta-population. However, they can provide some indication of relative population sizes per period. Estimates indicate annual population growth rates of -0.02% between the PPNA and EPPNB; 3.37% between the EPPNB and MPPNB; 0.37% between the MPPNB and LPPNB; and -0.08% between the LPPNB and PPNC. Average annual population growth throughout the PPN was estimated at 0.91%. This rate compares well with the upper end of Eshed *et al.*'s (2004) estimate for the southern Levant during the NDT (0.5-1%).

There are a number of potential causes for the negative growth rate between the PPNA and EPPNB (-0.02%). Firstly, there is ongoing debate regarding the presence of the EPPNB in the southern Levant and, therefore, it is possible that some sites which could be classified as EPPNB have been assigned to the PPNA or MPPNB (Kuijt 1997; 2003; Khalaily *et al.* 2007). Alternatively, some EPPNB sites may have been erroneously assigned to other periods based on the presence of PPNA or MPPNB cultural indicators. Secondly, chronological boundaries for the PPNA are difficult to define and, thus, the length of the PPNA (c. 1,200 years) may have been overestimated. Thirdly, this negative growth rate could reflect climatic deterioration that occurred in the region at the end of the PPNA, where unstable conditions brought dry periods followed by a gradual improvement in rainfall (Sanlaville 1996; Goring-Morris and Belfer-Cohen 1997). It is suggested that this caused some previously settled communities to revert to a more mobile subsistence strategy (Kuijt and Goring-Morris 2002). The minimal evidence for agricultural practices during the EPPNB indicates that most sites maintained hunter-gatherer subsistence strategies. A recent study of hunter-gatherer populations in Wyoming and Colorado between 13,000 and 6,000 cal BP revealed a long term annual population growth rate of 0.041% (Bettinger 2016; Zahid *et al.* 2016). Analysis of hunter-gatherer populations elsewhere revealed similar growth rates (Goldewijk *et al.* 2010; Peros *et al.* 2010; Johnson and Brook 2011; Shennan *et al.* 2013). As such, a low growth rate would be expected for the earliest PPN periods, which still relied heavily on hunter-gatherer subsistence strategies.

The high growth rate between the EPPNB and MPPNB (3.37%) could be a reflection of the adoption of agricultural practices, sometime between these two phases, that facilitated (and possibly resulted from) increased populations. There is a considerable increase in the numbers of sites of various sizes, indicating regional population increase (Kuijt and Goring-Morris 2002, p.424). The growth rate is considerably higher than that derived by Eshed *et al.* (2004) (0.5-1%) for the southern Levant during the NDT and those proposed for early formative villages undergoing the transition to agriculture elsewhere (0.08-0.25%) (Carneiro and Hilse 1966; Hassan 1981; Bandy 2001; Drennan and Peterson 2008). This high growth rate may be partly due to an under-assignment of EPPNB sites (as previously discussed) or an underestimated EPPNB period length (c. 200 years) due to unclear chronological boundaries. However, the high growth rate is consistent with evidence for improved climatic conditions, which facilitated a more sedentary lifestyle, including widespread transition to agriculture, the cultural control of wild animals and increasing adoption of pastoral practices relating to domesticated animals (Frumkin *et al.* 2001; Colledge *et al.* 2004; Colledge and Conolly 2007; Weiss and Zohary 2011; Makarewicz 2013; Martin and Edwards 2013). In addition, the increasing transition from curvilinear to rectilinear architecture and the innovation of two-storey building enabled more efficient use of settlement area and interior space. Greater compartmentalisation within dwellings may have reduced the perception of social crowding, potentially leading to larger dwelling unit sizes. Indeed, dwelling unit size estimates for MPPNB Site Types 1, 2, 3 and 4 are all marginally higher than estimates for the same site types during the EPPNB (Table 9.6). The high growth rate between the EPPNB and MPPNB could be interpreted as representing a ‘boom’ period following the introduction of agriculture, which appears to be a universal characteristic of communities undergoing the NDT (Bandy 2005; Whitehouse *et al.* 2014).

It has been noted that these ‘boom’ periods are often followed by a period of population decline around 800 years later (Bandy 2005; Whitehouse *et al.* 2014). The length of the MPPNB is generally estimated at around 800 years. If this theory is correct, a lower population growth rate should be expected to occur between the MPPNB and LPPNB.

Indeed, there does appear to be slower annual growth (0.37%) between these periods. Despite this, the total LPPNB population (P = 87,130) is considerably higher than the MPPNB population (P = 21,930). This reflects the considerably larger mean size of sites (MPPNB: 1.52 ha; LPPNB 5.21 ha). This, combined with the reduction in the numbers of small sites, indicates episodes of population aggregation rather than regional population increase (Kuijt 2008a, p.296). Higher settlement populations were facilitated by the widespread transition to rectilinear architecture, which enabled agglomerated, multi-storey construction and larger average dwelling unit sizes (Flannery 1972; 2002; Saidel 1993; Kuijt 2000; Rollefson and Kafafi 2013). Intensified agricultural practices, as well as the widespread adoption of pastoralism would have provided more stable food resources and surplus for trade purposes, improving settlement sustainability (Colledge and Conolly 2007; Weiss and Zohary 2011; Martin and Edwards 2013; Makarewicz 2009; 2013). Refined techniques for cultivation, processing, production and storage would have maximised the nutritional value of food resources and enabled more efficient use of resources, including wood, water and labour. Finally, a series of innovative technologies relating to water (and possibly air) management not only improved agricultural production, but also improved living conditions within these high density settlements, possibly reducing the spread of infectious disease (Köhler-Rollefson and Rollefson 1990; Mahasneh 1996; Kuijt and Chesson 2005; Fujii 2007; Kinzel 2013; White 2013).

There appears to have been a return to negative growth between the LPPNB and PPNC (-0.08%). There are several potential causes for this. Firstly, debate continues as to the presence of a PPNC period in this southern regions, and a number of potential PPNC sites may have been assigned to the LPPNB. Secondly, despite efforts to improve living conditions in the large LPPNB settlements, it is highly probable that without basic sanitation people living within these high density and crowded settlements were subject to a myriad of diseases (Kuijt and Chesson 2005). In addition, it is possible that communities were unable to sustain their daily calorific requirements. The intensive agricultural and pastoral practices that had been in place for at least the previous 1,300 years would certainly have caused some degree of landscape degradation, decreasing agricultural productivity (Köhler-Rollefson and Rollefson 1990). It has been suggested that a combination of such factors forced communities to disperse into smaller groups, migrate or even revert to a more nomadic lifestyle at the end of the PPN (Martin and Edwards 2013).

Table 9.7. Total population and annual population growth rates per period.

			Period				
		PPNA	*EPPNB*	*MPPNB*	*LPPNB*	*PPNC*
Number of sites			18	9	28	32	19
Total population estimate			3730	2831	21926	87132	38693
Length of period			1200	200	800	700	300
Population increase from preceding period		Number	-	-900	19096	65205	-48439
		Proportion	-	-0.2412	6.7460	2.9738	-0.5559
Annual population growth rate	Proportion		-	-0.0002	0.0337	0.0037	-0.0008
	%		-	**-0.02**	**3.37**	**0.37**	**-0.08**

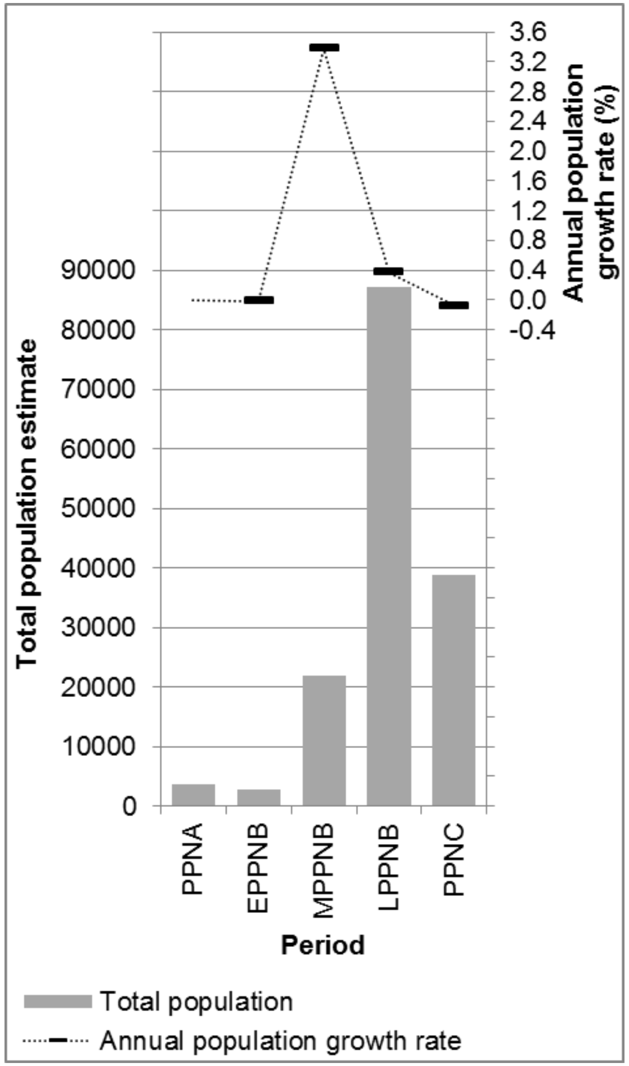

Figure 9.21. Total population and annual population growth rates per period.

9.6 Comparison with pre-existing estimates

Pre-existing estimates for 26 sites were compared to the revised estimate ranges produced in this investigation (Figure 9.22). The majority of the pre-existing estimates were produced by Kuijt (2000; 2008a), based on:

1. Estimated site area and 90 and 294 people per hectare (Watson 1979, pp.35-47; Kramer 1982, p.162; van Beek 1982, pp.64-65) (Kuijt 2000).
2. The mean population of the largest five settlements based on 294 people per hectare (van Beek 1982) (Kuijt 2000).
3. Period-based site extents (PPNA: 1 ha; MPPNB: 2.5 ha; LPPNB: 10 ha; PPNC: 5 ha) and 90 people per hectare (Kuijt 2008a).

Campbell (2009, p.137) employed similar density coefficients to estimate the population of ‘Ain Ghazal, Basta and Jericho, whilst Rollefson and Köhler-Rollefson (1989, p.75) and Ladah (2006, p.150) used van Beek’s (1982) density coefficient to estimate the population of ‘Ain Ghazal and Ghwair I, respectively.

Kuijt (2000, pp.82-85) emphasises the use of such estimates for comparative analysis, rather than as absolute representations of population size. However, there are a number of issues with these estimates that may impact the efficacy of any subsequent analysis. Firstly, it appears that the commonly utilised density coefficients are too low for PPN central and southern Levantine villages. In this investigation, the majority of re-calculated population density values range from around 400 to 750 people per hectare, despite being based on adult population only. If children were factored into the SPF population estimates, this would further increase the density values achieved in this investigation.

When the commonly utilised density values were applied, this resulted in insufficient population levels in the assessable areas of villages analysed at the micro-level (see Section 10.1.2). Secondly, the application of mean maximum population sizes inflates estimates of smaller sites. Thirdly, the application of period-based site extents does not reflect the variability in settlement size and produces the same population estimate for sites of considerably different sizes. For example, Kuijt (2008a) applied a site extent of one hectare to estimate the population of both PPNA Jericho and Nahal Oren at 90 people each, despite these sites being estimated at around 2.5 hectares (Kenyon 1981, p.238; Bar-Yosef 1986, p.157) and 0.05 hectares (Stekelis and Yizraely 1963; Banning 1998, p.195), respectively. In this investigation, PPNA Jericho was estimated at around 1,060 people (P = 740-1,650), whilst Nahal Oren was estimated at around 30 people (P = 24-43). These estimates more accurately reflect the estimated site extents and the settlement evidence within these sites.

Despite the vastly different methods utilised, almost half of the pre-existing estimates overlap or compare well with the revised estimate ranges. This includes LPPNB el-Hemmeh, which was previously estimated at 900 people based on 90 people per hectare and a suggested average LPPNB site extent of 10 hectares (Kuijt 2008a). In this investigation, el-Hemmeh was estimated at around 660 people (P = 530-800) based on an estimated site extent of one hectare. An additional examples is Ba'ja, which was estimated at 580 to 610 people in this investigation. Gebel and Hermansen (1999, p.19) previously estimated the population of Ba'ja at 400 to 500 people based on a hypothesised 50 to 60 families of eight to 10 people each.

Although these estimates compare well with those derived in this investigation, the purpose underlying the reconstruction of the pre-existing estimates is generally not aimed at precision or accuracy, and the underlying methodologies are generally not sufficiently explained or justified. Conversely, the estimates produced in this investigation are based on detailed assessment of the structural remains of several villages and statistical analyses of various population parameters, which enabled the development of a site type classification system and constants specifically aimed at producing absolute population estimates. These constants were applied to individually estimated site extents to produce mean and absolute minimum and maximum population estimates for each site. The more empirically and statistically robust methodology employed in this investigation has produced far more precise and accurate estimates than previously existed.

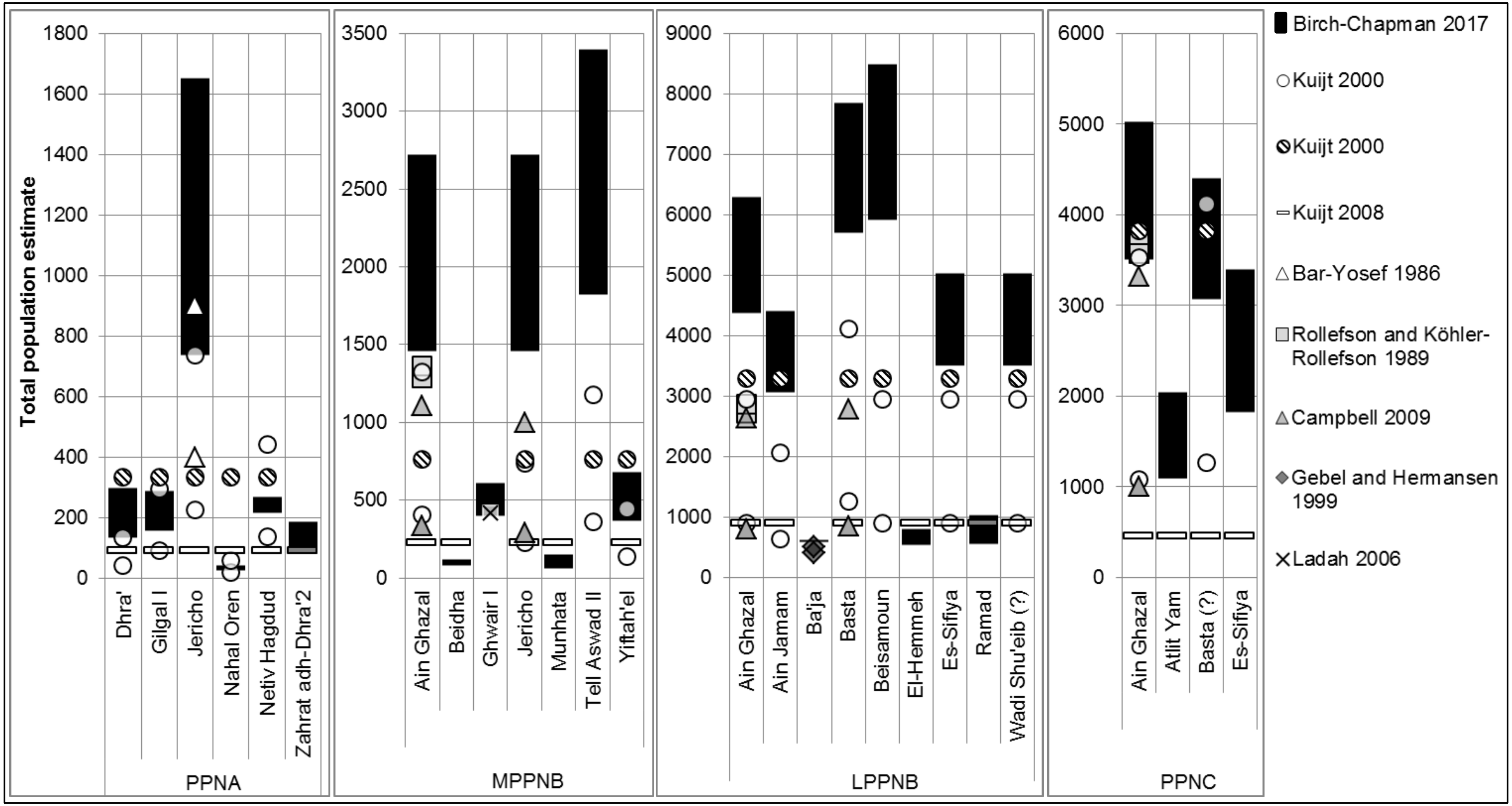

Figure 9.22. Comparison of revised and pre-existing estimates.

9.7 Proposed formulae for estimating PPN village populations

Based on the estimates achieved in this investigation, a series of allometric growth formulae are proposed for estimating the minimum, mean and maximum (adult) population size of central and southern Levantine PPN village populations (Table 9.9; Figure 9.24). Scaling exponents for the majority of these formulae are between 0.86 and one. This falls within the range of scaling exponents proposed by Wiessner (1974) for village (b = 1) and urban (b = 0.6667) settlements, with the minimum exponent comparing well to that derived by Naroll (1962) (b = 0.84195).

Assessment of the results indicated that structural density accounted for some of the differences between mean micro-level estimates and mean systematic estimates. In several cases, considerably higher or lower micro-level estimates coincided with considerably higher or lower than average structural density (i.e. ‘Ain Abu Nekheileh: 95%, Site Type 1 mean: 64%; Ghwair I: 48% and LPPNB el-Hemmeh: 80%, Site Type 4 mean: 64%). Site type classification would, therefore, benefit from consideration of the degree of structural density. Unfortunately, this was not possible due to the insufficient number of sites available for micro-level assessment and an inability to estimate structural density within the majority of sites in the village database.

Regression analysis was conducted in SPSS to determine the correlation between structural density and the differences between mean micro-level and systematic estimates (Appendix E.3). Regression analysis determines the correlation between an independent variable (i.e. the degree of difference between micro-level and systematic estimates) and dependent variables that may impact the independent variable (i.e. structural density). Pearson’s correlation coefficient (r) is a measure of the strength of association between these variables. The r^2 value is the percentage of variance explained by the model. This is effectively a proportion value, indicating the percentage of variation in the independent variable that is due to variations in the dependent variable (Nau 2017). A significance value (p) of less than .05 indicates a significant correlation.

Regression analysis indicated that structural density accounts for 27.4% (r = .523; r^2 = .274; p = .066) of the differences between mean micro-level estimates and systematic estimates, although the significance value is above the significance threshold (Table 9.8; Figure 9.23).

Unfortunately, due to the variable relationship between structural density and the difference between mean micro-level and systematic estimates, a standard formula, or addition to the formulae, could not be derived to account for differences in structural density. As such, it is suggested that the mean formulae correspond to the mean structural density. Where higher or lower than average density occurs, the maximum and minimum formulae, respectively, may produce more accurate population estimates.

Table 9.8. Correlation between structural density and the difference between mean micro-level and systematic estimates.

Pearson Correlation (*r*)	.523
R Square (r^2)	.274
Sig. (2-tailed) (*p*)*	.066
N	13

* $p < .05$ = significant correlation.

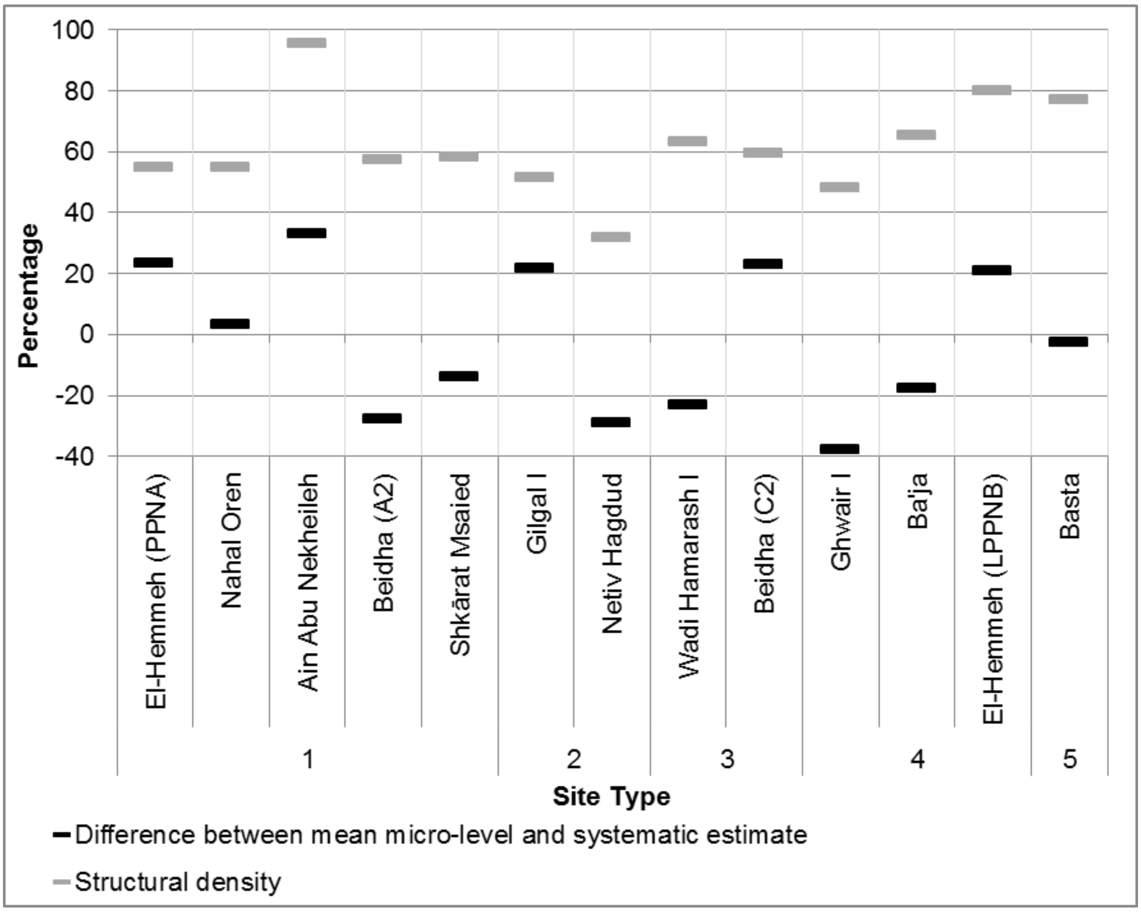

Figure 9.23. Correlation between structural density and the difference between mean micro-level and systematic estimates.

Table 9.9. Proposed allometric growth formulae for estimating PPN village populations indicating average structural density corresponding to the mean formulae.

Site type	Formulae *Minimum*	***Mean***	*Maximum*	Structural density corresponding to mean formula (%)
1	$P = 346A^{0.8638}$	$\mathbf{P = 535A^{0.9139}}$	$P = 825A^{0.9466}$	64
2	$P = 300A^{0.9395}$	$\mathbf{P = 419A^{0.9634}}$	$P = 628A^{1.0023}$	42
3	$P = 237A^{0.6105}$	$\mathbf{P = 288A^{0.5635}}$	$P = 324A^{0.4768}$	61
4	$P = 383A^{0.9626}$	$\mathbf{P = 527A^{0.9927}}$	$P = 666A^{1.0111}$	64
5	$P = 438A^{0.9997}$	$\mathbf{P = 520A^{1.0004}}$	$P = 646A^{0.9863}$	77
Universal	$\mathbf{P = 384A^{0.976}}$	$\mathbf{P = 539A^{0.96}}$	$\mathbf{P = 723A^{0.9256}}$	**62**

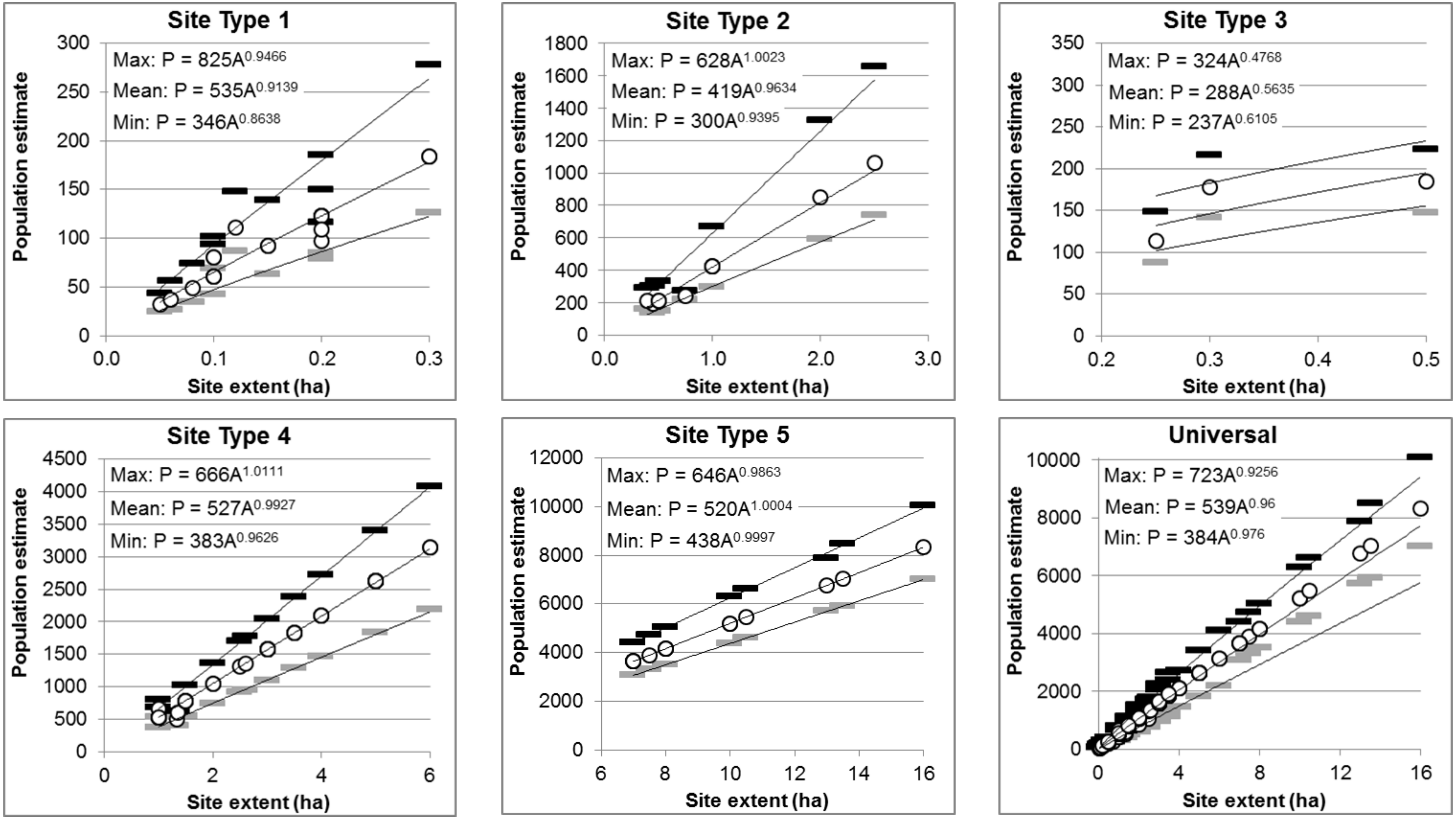

Figure 9.24. Allometric growth formulae for reconstructing minimum, mean and maximum population estimates for central and southern Levantine PPN villages.

9.8 Summary

All PPN central and southern Levantine settlements and settlement phases identified as villages (*n* = 106) were categorised into five site types specifically for the purpose of reconstructing population estimates. These include Type 1: small (< 0.4 ha) (*n* = 23) and Type 2: large (≥ 0.4 ha) (*n* = 10) villages with predominantly curvilinear architecture; and Type 3: small (≤ 0.5 ha) (*n* = 3), Type 4: large (0.6-6 ha) (*n* = 47) and Type 5: very large (≥ 7 ha) (*n* = 14) villages with predominantly rectilinear architecture. The remainder of villages were of Unknown type (*n* = 9). Type 1 and 2 villages occur only in the earlier PPN (PPNA-MPPNB), whilst Type 4 and 5 villages occur in the later PPN (MPPNB-PPNC). Type 3 villages occur during the MPPNB and LPPNB. A tendency to assign larger site extents to settlements with rectilinear architecture may have resulted in the incorrect assignment of several potential Type 3 villages as Type 4 villages. Accurate site extent estimates are essential for producing more precise population estimates, as there is often a strong correlation between site extent and population size. Attempts were made in this investigation to establish the most precise site extents from the available information. However, more detailed assessment of site extent in the field and using geographical information systems would be beneficial for further demographic studies.

An assessment of population estimate ranges and statistical analysis of the differences between micro-level and systematic estimates identified three suitable methods for final estimate reconstruction of type classed sites: the storage provisions formulae (SPF), the settlement population density coefficient method (SPDC) and Wiessner's (1974) village allometric growth formula (AGF2). For sites of Unknown type, analysis indicated that the storage provisions formula (SPF) was the only suitable method.

An assessment of the revised population estimates and the available archaeological evidence confirmed several previously hypothesised group size thresholds relating to changing subsistence practices, mechanisms for reducing scalar stress and promoting social cohesion, and the emergence of social complexity. In several cases, developments occur at lower than expected population sizes. This could reflect cumulative cultural evolution and/or the extensive networks that existed throughout the PPN, with several smaller settlements and possibly nearby nomadic groups effectively acting as a larger interactive population. The precise population estimates produced in this investigation and the detailed archaeological evidence for several sites present a unique opportunity to hypothesise about further group size thresholds specifically relating to intensified agricultural and pastoral practices, the elaboration of ritual practices, and innovative technological developments, including architectural transitions, manufacturing processes and water or air management.

A summary of density estimates per site type revealed limited variation in residential floor area per person (mean: 3.08-3.7 m^2), though did highlight distinct differences in dwelling unit sizes and population density. The results indicate that Type 1 sites may not have been predominantly occupied by nuclear family dwelling units (range: 1-4.9 people), with estimates for Type 5 sites providing the best evidence for extended family dwelling units (range: 4.7-8.4 people). Despite the low dwelling unit sizes in many Type 1 sites, these demonstrated the highest population density (range: 400-1,230). All mean density estimates (320-930 people/ha) exceed the commonly utilised density coefficients of 90 to 294 people per hectare, despite being based on adult population only (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009).

The mean annual population growth rate (0.91%) falls at the upper end of the range proposed by Eshed *et al.* (2004) for southern Levantine populations during the NDT (0.5-1%). A slow, or perhaps negative, annual growth rate between the PPNA and EPPNB (-0.02%) may be linked to climatic deterioration and/or theoretical debate regarding the existence of an EPPNB period in southern regions. Elevated annual growth rates between the EPPNB and MPPNB (3.37%), and through to the LPPNB (0.37%) correspond to the widespread adoption of agricultural practices, followed by pastoral practices, and the transition to rectilinear architecture. Apparent negative annual growth at the end of the PPN (-0.08%) could reflect population decline resulting from climatic deterioration, landscape degradation and infectious disease, or a combination of these (Köhler-Rollefson and Rollefson 1990; Kuijt and Chesson 2005).

A comparison of the pre-existing estimates with the revised estimates proposed in this analysis revealed variable differences. Several methodological issues relating to the previous estimates were highlighted, including the almost ubiquitous use of density coefficients that were found to be too low in this investigation. In addition, site extents were often not sufficiently assessed or period-based site extents were systematically applied to settlements of vastly different sizes, producing the same population estimates for these sites. Due to issues associated with the pre-exiting estimates, interpretations based on these estimates should be re-examined.

Based on the final estimate ranges produced in this investigation, a series of allometric growth formulae are presented to estimate minimum, mean and maximum (adult) population sizes for PPN villages in future. Structural density was found to have some impact on differences between micro-level and systematic estimates. As such, the mean formulae are suggested to correspond to the mean structural density values. Minimum (lower than average) and maximum (higher than average) formulae could be utilised where structural density is identified as differing from the average.

10 Theoretical and Methodological Implications

The aim of this thesis was to completely revise the manner in which population estimates of PPN villages are reconstructed, with a view to producing more precise and accurate estimates for subsequent demographic analyses. This aim was based on the recognition that pre-existing population estimates for PPN villages are underpinned by limited theoretical and methodological frameworks as these estimates were constructed for comparative analyses rather than as absolute demographic data.

The reluctance to produce absolute estimates in previous investigations has stemmed from the myriad of theoretical and methodological difficulties involved. Some of the major issues considered in this investigation relate to the dichotomy between public and private space and the ability to identify residential as opposed to non-residential areas, particularly within earlier PPN settlements (Watson 1978; Kramer 1982; Watkins 1990; Byrd 1994; 2002; 2005a; Finlayson *et al.* 2011). Several additional issues addressed in this investigation relate to extrapolating information from the excavated area to make whole site conclusions. Of particular importance are the accuracy of site extent estimates, consideration of the representativeness of the excavated area and the ability to factor uninhabited areas into calculations of population size based on estimated total site extent (Shiloh 1980; Broshi and Gophna 1984; Verhoeven 2006; Goring-Morris and Belfer-Cohen 2008; Bandy and Janusek 2005; Wossinik 2009; Peterson and Shelach 2012). Unfortunately, due to the constraints of this thesis, some aspects cannot be explored in detail. These include changes in population size relating to the degree of sedentism of some community members and periods of settlement aggregation related to cultural events or seasonal activities (Verhoeven 2006).

This analysis focuses on a re-evaluation of current theory relating to PPN village population density, including an assessment of assumptions regarding dwelling unit size and composition, and the use of ethnographically derived population density coefficients to estimate population. The major methodological contributions of this investigation are highlighted, including a discussion of the new method developed in this investigation: the storage provisions formulae (SPF); and the use of Bayesian chronological modelling to estimate building use-life and phase length for reconstructing structural contemporaneity values. The new classification system for PPN villages is discussed, in addition to the newly proposed formulae for estimating PPN village populations in future. The limitations and opportunities relating to these methodological approaches are outlined.

The population estimates derived in this investigation provide opportunities to explore numerous aspects of human social development. In this research, archaeological evidence is interpreted in light of the revised population estimates to determine the validity of previously hypothesised group size thresholds and to establish additional potential thresholds relating to three major aspects of cultural evolution during the NDT: changing subsistence practices; mechanisms for reducing scalar stress and promoting social cohesion; and emerging social complexity.

10.1 Re-evaluation of theory relating to PPN village population density

10.1.1 Dwelling unit size and composition

It has long been argued that PPN central and southern Levantine villages comprised predominantly nuclear family dwelling units, with larger compartmentalised structures perhaps accommodating extended families (Kramer 1982; Banning and Byrd 1987; Rollefson and Köhler-Rollefson 1989; Düring 2001; Byrd 2002; 2005a; Kuijt *et al.* 2011; Rollefson and Kafafi 2013). These assumptions are largely based on ethnographic analogies with 20th Century villages and towns in Southwest Asia (Sweet 1960; Wright 1969; Antoun 1972; Kramer 1979; 1982; van Beek 1982). However, the application of these conceptually defined terms and the use of these ethnographic comparatives is questionable given the potential variability in PPN dwelling unit types and the differences that occur between settlements.

Flannery (1972; 2002, p.417) identified two main types of village settlement. The first comprised small compounds (usually of circular huts) with shared storage, accommodating extended family groups with dwellings occupied by individuals and smaller units. Flannery defines the second type as "true villages". These comprise large compounds of houses (usually rectilinear) of a sufficient size to accommodate nuclear family dwelling units and associated with private storage facilities. These two settlement types are roughly analogous to PPN settlements, although some sites with curvilinear architecture, particularly during the MPPNB (i.e. Shkārat Msaied and 'Ain Abu Nekheileh) also have evidence for private storage facilities, reflecting an increasing dependence on agriculture during this period (Wills 1992; Kuijt 2008a).

Finlayson *et al.* (2011, p.131) argue that the variability in structural forms and sizes within PPN settlements with curvilinear architecture does not indicate a standardised domestic unit type. At some sites, particularly during the PPNA, there is limited evidence to suggest a specifically residential purpose for any structure (i.e. PPNA WF16 and Jerf el Ahmar) (Finlayson *et al.* 2011). In this investigation, some sites demonstrate a clearer distinction between residential and non-residential structures (i.e. PPNA Nahal Oren, PPNA Gilgal I and MPPNB Shkārat Msaied) (Noy *et al.* 1973;

Noy 1979; 1989; Bar-Yosef 1998; Jensen *et al.* 2005; Hermansen *et al.* 2006; Goring-Morris and Belfer-Cohen 2008; Rosenberg 2008; Bar-Yosef *et al.* 2010a; Kinzel 2013). Within some settlements, the clustering of relatively small, single-celled, curvilinear structures with undifferentiated floor space has been interpreted as representing occupation by individuals, pairs or other small units as part of an extended family (i.e. PPNA Nahal Oren and PPNA/EPPNB el-Hemmeh) (Finlayson 1972; 2002; Bar-Yosef 1998). Larger and occasionally compartmentalised structures have been interpreted as representing larger co-resident groups, potentially comprising nuclear family units (i.e. PPNA Gilgal I, PPNA Netiv Hagdud, MPPNB Shkārat Msaied and MPPNB ‘Ain Abu Nekheileh) (Bar-Yosef *et al.* 1980; 1991; Henry *et al.* 2003). Where evidence exists for dwelling-based food-related activities, including private storage facilities, these dwelling units are often considered to represent economically independent households (Rosenberg 2008). However, Baird *et al.* (2016) argue that these institutionalised household units probably formed part of supra-household economies.

The shift from curvilinear to rectilinear architecture has been associated with the transition from co-resident extended family settlements engaged in communal subsistence strategies to more economically independent and competitive nuclear family units (Saidel 1993). Rectilinear architecture is more adaptable than curvilinear architecture, enabling more defined separation between residential units; greater compartmentalisation of space and activities within these units; and the ability for both horizontal and vertical expansion of structures as needed (Flannery 1972). This architectural transition has been related to a breakdown of the close ties that existed within extended family units due to population growth (Saidel 1993). It is suggested that large extended families split into smaller nuclear family units, each of whom were responsible for the risks and rewards of family-based production (Flannery 1972; 2002). Productive family units would have gained economic advantage over their less productive neighbours (Saidel 1993; Flannery 2002). The increasing separation between public and private space and restrictions on accessibility of stored goods that were kept in permanent storage facilities within these dwellings may reflect strategies to avoid jealousy and conflict with these neighbours (Wiessner 1982).

More elaborate rectilinear residential architecture (including multi-storey construction) is considered by some to reflect the emergence of extended family households, whose combined labour investments significantly increased productive outputs (Rollefson and Kafafi 2013). These units have been interpreted as families of prestigious ritual leaders and highly productive agricultural investors (Kuijt 1995). In ethnographic contexts, dwellings occupied by multi-family households usually have multiple sets of features, including hearths, kitchens and storage facilities, as well as additional rooms constructed to house offspring and their families (Starna 1980; Kramer 1982; Flannery 2002). 'Tri-modal' structures that include (1) small, square rooms, probably for storage; (2) elongated rooms, probably for workshop activities or sleeping; and (3) large rooms, probably courtyard areas for cooking and living are also suggested to represent multi-family units (Flannery 2002, p.426).

Within PPN dwellings with rectilinear architecture, there is little evidence for multiple hearths or other multiple sets of features, except perhaps possible sleeping platforms of the type found at Çatalhöyük (Mellaart 1967; Düring 2001). However, multiple storage facilities are commonplace and there is evidence to suggest 'tri-modal' structures at MPPNB Wadi Hamarash I and LPPNB Basta, and possible later additions of rooms at Wadi Hamarash I, MPPNB Ghwair I and LPPNB Ba'ja (Rollefson and Köhler-Rollefson 1989; Gebel and Hermansen 1999; Hemsley 2008; Rollefson and Kafafi 2013; Sampson 2013a). At Basta, and potentially LPPNB el-Hemmeh, horizontal addition of rooms was impossible due to building of houses on adjoining terraces and/or with shared external walls (Nissen 2006). It has been suggested that these houses were constructed based on a predetermined plan that factored in the need to house larger dwelling units. This pre-planning is also evident at Beidha Subphase C2, which comprised relatively standardised two-storey structures across the site (Byrd 2005a). In the majority of cases, there is variable evidence for second storeys and considerable variability in the size and form of structures. This has been interpreted as reflecting increasing social differentiation related to the production capacities of dwelling units of differing size and composition (Kuijt 1995).

In this investigation, dwelling unit size estimates for PPN villages with curvilinear architecture support Finlayson *et al.*'s (2011) argument regarding variability in dwelling unit composition (mean micro-level estimates: 1.2-4.8 people). Estimates derived for PPNA el-Hemmeh (0.9-1.5 people/dwelling) and MPPNB Beidha Subphase B2 (1.5-2.2 people) indicate that dwellings within these settlements may have been predominantly inhabited by individuals or pairs, possibly as part of an extended family unit, supporting assertions made by Flannery (1972; 2002) and Bar-Yosef (1998). In many ways, these settlements more closely resemble those of contemporary hunter-gatherer groups than sedentary agricultural groups, though with more durable architecture (Cook and Heizer 1968; Wiessner 1982; Whitelaw 1991; Flannery 2002). Higher estimates derived for PPNA Gilgal I (2.3-4.7 people), PPNA Netiv Hagdud (4.2-5.3 people) and MPPNB Shkārat Msaied (2.6-4.9 people) indicate larger dwelling units, potentially comprising nuclear families, or perhaps even extended family units.

Mean dwelling unit size estimates for PPN villages with rectilinear architecture (mean micro-level estimates: 2.7-5.7 people) indicate that all dwellings with rectilinear architecture had the capacity to house nuclear family units. Dwelling unit size estimates of greater than four people could even reflect extended family units depending on the stature of individuals (i.e. MPPNB Ghwair I: 3.8-5.8 people; LPPNB Beidha Subphase C2: 3.9-6.4 people).

It must be emphasised, however, that dwelling unit size estimates relate to adults only as these are derived from SPF population size estimates. If children were factored into these estimates, or if the stature of individuals was less than the human heights employed in Hemsley's (2008) original assessment (1.65 m and 1.83 m), the population size and dwelling unit size estimates would be higher. Conversely, if animals occupied some of the residential area and this could be somehow factored into the estimates, these estimates would be lower. Further work aimed at refining the SPF method to consider the presence of children and animals is essential.

Regardless, the considerable difference between mean dwelling unit size estimates for PPN villages with curvilinear and rectilinear architecture supports arguments relating to the changing composition and function of dwelling units and the relationship between this and architectural form. However, inferences regarding dwelling composition based on these estimates are conjectural and require much more detailed analysis of the spatial distribution of domestic artefacts to determine co-residence patterns (Flannery 2002, p.420; Byrd 2005a, p.121).

Despite Byrd's (2002, p.85) suggestion that household size and composition did not profoundly change throughout the PPN, dwelling unit size estimates achieved in this investigation, together with evidence for variability in architectural forms, subsistence practices and social organisation indicates clear differences throughout the PPN, even within the use-life of individual structures. This analysis has highlighted four broad dwelling unit types, each with their own potential social implications:

1. Individual, paired or very small units ($P \leq 3$), perhaps as part of an extended family group.
2. Small nuclear family units representing the transition from a co-resident extended family group to more economically independent nuclear family units.
3. Larger nuclear family units associated with increasing economic competition and differentiation between households.
4. Extended family units reflecting well established household based economic practices, social differentiation and social inequality.

An assessment of PPN central and southern Levantine settlements in association with the estimates derived from this analysis indicates that the first three types probably occurred within settlements of predominantly curvilinear residential architecture, whilst settlements with rectilinear residential architecture probably comprise types three and four only.

10.1.2 The settlement population density coefficient (SPDC) method and commonly utilised density values

Almost all pre-existing population estimates for PPN central and southern Levantine villages are based on multiplication of site extent by the same ethnographically derived population density coefficients (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009). The minimum coefficient is usually 90 people per hectare based on research conducted in Iran (Jacobs 1979; Watson 1979; Kramer 1982), whilst the maximum is always based on van Beek's (1982, pp.64-65) estimate of 286 to 302 people per hectare (mean: 294 people/ha) at Tell Marib, North Yemen. Occasionally, a mid-range value of around 150 people per hectare is employed based on Kramer's (1979; 1982) research in Iran and regional ethnographic analyses that indicate general population densities of between 100 and 200 people per hectare (Sumner 1979; Shiloh 1980; Adams 1981; Aurenche 1981; Kramer 1982; Zorn 1994; Wossinik 2009). Ethnographic villages used to derive these density values usually comprise a mixture of nuclear and extended family dwelling units, though the former are more predominant.

This investigation has highlighted several theoretical and methodological issues with this technique. The use of constants derived from ethnographic analyses of mainly Southwest Asian communities is questionable, given the considerably different environmental context and the wide array of modern impacts on settlement layout, including religion, community facilities and infrastructure for health, education and transport (Adams 1981). In addition, these modern villages often accommodate multi-family households residing in compounds with large courtyard areas and rooms larger than those identified within PPN settlements (Kramer 1982). These ethnographic comparatives may be suitable for later PPN settlements that demonstrate similar architectural features and have the capacity for extended family dwelling units. However, they are not suitable for earlier PPN settlements, particularly those with curvilinear architecture.

The SPDC method is based on the assumption that population density is constant within all PPN settlements. The use of standardised density coefficients for all sites clearly does not reflect the great variability in architectural forms and spatial distribution both within and between settlements, or the underlying social conditions and subsistence practices that influence use of space (Finkelstein 1990, p.50). In addition, application of the commonly utilised SPDC range (90-294 people/ha) produces the same population estimates for sites of equivalent estimated total site extent regardless of intra-site organisation or other impacting factors, such as topographical context, climate or perceptions relating to privacy, space and overcrowding. Further, the large range in these density values results in broad population estimate ranges that become increasingly uninformative as settlement size increases (as for Basta: Figure 10.1). These commonly utilised density coefficients produce maximum population estimates that are around 230% higher than the minimum population estimate. This is far greater than the range produced by the final proposed estimates in this investigation, where the maximum estimate is between 25% and 85% higher than the minimum estimate.

When micro-level population estimates based on the SPDC method were converted to population and dwelling unit sizes in the assessable area, it became apparent that even the maximum commonly utilised value (294 people/ha) may underestimate population (Figure 10.1). Conversion of population estimates based on this value produced dwelling unit sizes of around one or fewer people for seven of the 15 sites assessed, including ‘Ain Abu Nekheileh (n = 0.68) and LPPNB el-Hemmeh (n = 1.19). Estimates of two to three people per dwelling were produced for a further six sites, including Beidha Subphase C2 (n = 2.41), Ba’ja (n = 2.29) and Basta (n = 3.19). It is highly improbable that the dwellings within these settlements were occupied by such small units given the evidence for increasing household-based economic activities and the large size of interior space (Gebel and Hermansen 1999; Byrd 2005a; Rollefson and Kafafi 2013).

The converted dwelling unit size estimate produced for Netiv Hagdud, based on the maximum density coefficient (4.36 people/dwelling), suggests that this density value may be suitable for this site. Netiv Hagdud produced the lowest density value in this analysis (286-357 people/ha) due to a combination of low structural density (31.7%) and low structural contemporaneity (60%) values. This low contemporaneity value also resulted in a comparatively lower number of dwellings used to convert the maximum SPDC population estimate to dwelling unit size, resulting in more people per dwelling.

The validity of these converted estimates depends on the accuracy of dwelling identification and structural contemporaneity values. If the number of contemporaneously occupied dwellings was actually fewer than estimated, then the dwelling unit size estimates based on the maximum commonly utilised SPDC would be higher. ‘Ain Abu Nekheileh provides a good case study for examining this (see Section 7.1.8). Here, all nine large structures were identified as potential dwellings and a relatively low contemporaneity value of 65% was derived from Bayesian chronological modelling of phase length and building use-life. At least two of the structures could be re-interpreted as being non-residential: Locus 20 contained high spherulite frequencies, indicating a change of function from a domestic structure to an animal pen at some point (Henry *et al.* 2003, p.12; Henry and Albert 2004, p.91); and Locus 11 has an atypical layout and appears to lack the built-in storage features that exist within most of the other structures. If these structures are removed from the dwelling count, this results in an estimated 4.55 contemporaneous dwellings in the assessable area and an increase in the dwelling unit size based on the maximum SPDC (294 people/ha) to 0.87 people per dwelling (previously 0.68 people/dwelling). To increase this to one person per dwelling, a further dwelling would need to be re-assigned as non-residential, resulting in around four contemporaneous dwellings in the assessable area. Alternatively, a dwelling unit size of one would be achieved if the dwelling count remained the same (*n* = 9) and a contemporaneity value of around 45% was applied. These adjustments increase the dwelling unit size estimate to the minimum value possible.

However, the final dwelling unit size proposed for ‘Ain Abu Nekheileh in this investigation is 1.8 to 2.8 people. Consideration of children in the SPF method would have produced a larger dwelling unit size. To achieve even the minimum estimate (1.8 people), conversion of the maximum SPDC population estimate would need to be based on around 2.2 contemporaneous dwellings in the assessable area, achievable either by:

1. reducing the number of dwellings identified in the assessable area to 3.5;
2. applying a contemporaneity value of around 25% to the nine dwellings identified; or,
3. combining reduced values, for example five dwellings at 45% contemporaneity.

The extent of the site plan and assessment of the architectural features indicates that there were probably more than 2.2 contemporaneous dwellings in this area (see Section 7.1.8). Therefore, the maximum commonly used density coefficient (294 people/ha) appears too low to accurately estimate the population of this site.

This brief assessment provides additional support for the re-evaluation of the commonly utilised density values. As part of this re-evaluation, density values were reconstructed from the final micro-level population estimates produced in this investigation (Figure 10.1). Mean population density estimates ranged from around 320 people per hectare (PPNA Netiv Hagdud) to around 930 people per hectare (MPPNB ‘Ain Abu Nekheileh), with an overall mean of around 580 people per hectare. These density estimates would be higher if children were factored into the SPF population estimates.

The highest densities were recorded for small villages with curvilinear architecture (Type 1). In a cross-cultural analysis of forager communities, Whitelaw (1991, p.151) identified higher densities within settlements occupied by an extended family group, whose social and subsistence strategies were based on cooperative interaction. The high densities recorded in Type 1 villages could support their interpretation as extended family group compounds with a communal subsistence focus (Flannery 1972; 2002; Bar-Yosef 1998).

All except three of the minimum re-calculated SPDCs far exceed the maximum commonly used density coefficient (294 people/ha) and all but two of the maximum re-calculated SPDCs fall within the upper density limit suggested for early agricultural villages (1,000 people/ha) (Fletcher 1981). The majority fall within the range of around 400 to 750 people per hectare. These estimates are comparable to those derived for several hunter-gatherer camps, as well as enclosed Bronze Age and Iron Age settlements (Jeremias 1969; Shiloh 1980; Whitelaw 1983; Zorn 1994; Wossinik 2009; Kennedy 2013).

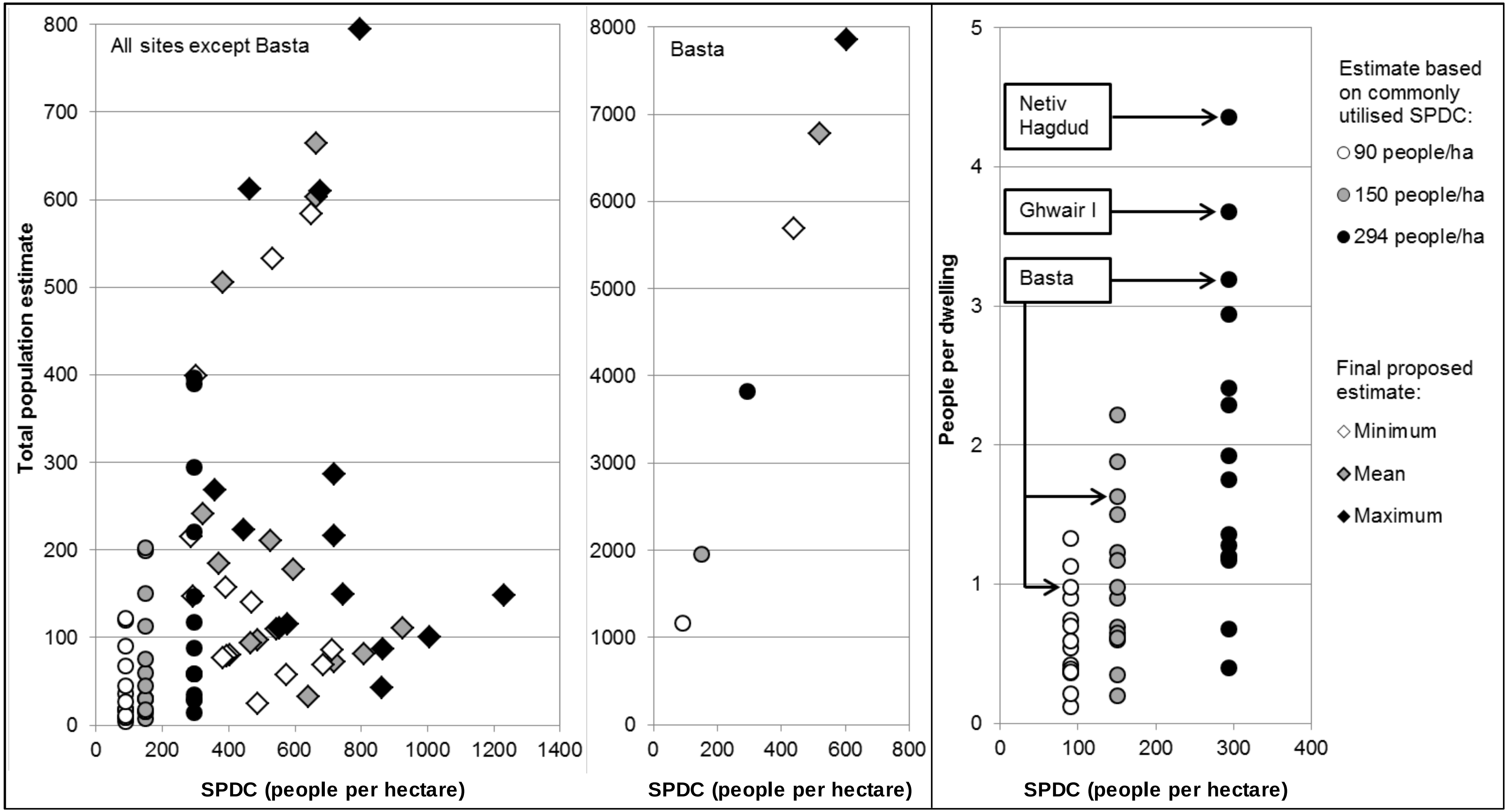

Figure 10.1. Micro-level estimates of population size and people per dwelling derived from commonly utilised SPDCs, and SPDCs re-calculated from final proposed estimate range.

Archaeologists continue to use low density values to estimate PPN village populations despite acknowledging that those with multi-storey structures, potentially occupied by large nuclear or extended families (i.e. Basta and Ghwair I), may have had higher densities than commonly recognised (Kuijt 2000, p.93; Flannery 2002, p.429). This re-evaluation of commonly utilised density coefficients has revealed that these are too low to accurately estimate PPN village populations, at least in the central and southern Levant, and that higher values of around 400 to 750 should be applied. If these high densities are characteristic of these villages, this raises a number of questions about how people were able to live in such densely populated settlements without sophisticated water or transport technologies, and calls for further research into the relationship between demographic factors and the causes and consequences of developments in subsistence strategies, architecture, economic practices and social organisation.

10.2 Major methodological contributions

This research incorporates several significant contributions to the methodological framework for reconstructing demographic parameters of central and southern Levantine PPN villages, with far-reaching implications for demographic analyses of comparable settlements in other periods and locations.

A major objective of this research was to explore methods that relied predominantly on archaeological evidence, rather than on assumptions and constants derived from ethnographic research. This objective was based on the recognition that considerable variability exists within both the ethnographic and archaeological records, and that the true comparability between modern and prehistoric settlements can never be verified, making these comparisons somewhat redundant. In addition, micro-level application of commonly utilised ethnographically derived constants relating to population density (i.e. people/dwelling, RADC and SPDC) produced considerably different estimates, highlighting the potential inapplicability of one or more of these constants for estimating and assessing PPN central and southern Levantine village populations. Therefore, this investigation explored and statistically assessed methods based on empirical archaeological data with the aim of developing a method that could be widely adopted by archaeologists to produce justifiable estimates without incorporating ethnographic assumptions or complicated statistical analyses.

The most robust and valid method identified for micro-level analysis in this investigation was the newly developed storage provisions formula (SPF). This method, combined with a more statistically robust method for establishing structural contemporaneity values from archaeological, ethnographic and experimental research and Bayesian chronological modelling of building use-life and phase length, produced population estimates that are more accurate and precise than the pre-existing estimates. From the estimates produced in this investigation, a site type classification system was developed, enabling constants to be applied to settlement sizes to produce site-specific population estimates for all villages in the PPN central and southern Levantine village database. From these estimates, a series of allometric growth formulae were constructed to estimate population size of comparable settlements in future based on an assigned site type and an estimated total site extent. These methodological contributions are outlined in detail below.

10.2.1 Storage provisions formulae (SPF)

The storage provisions formula (SPF) is a unique method established in this investigation using data produced by Hemsley (2008). Three formulae were constructed correlating available residential floor area (not including access routes, hearths and activity zones) to the maximum number of adult sleeping occupants based on three different amounts of personal annual storage in the residential floor area (none: $P = 0.3944A - 0.375$; moderate - 0.46 m^3: $P = 0.2477A + 0.0339$; maximum - 2 x 0.46 m^3: $P = 0.1903A + 0.3976$).

The SPF is considered the most valid and robust method in this investigation for several reasons. It is almost exclusively based on archaeological evidence and incorporates fewer assumptions than any other method used for reconstructing population estimates in this investigation. In addition, the SPF method generally produced tighter estimates than other methods, even when applied systematically to all sites in the PPN village database. This was particularly the case when one or more of the formulae could be removed from the final estimate range due to (1) insufficient dwelling unit sizes (i.e. less than one person per dwelling) resulting from application of the formulae; or (2) evidence for or against storage within the residential floor area. Where dwellings were associated with substantial designated storage space separate from the residential floor area (i.e. Beidha Subphase C2 and LPPNB el-Hemmeh), it was suggested that the maximum amount of storage would not occur within the residential floor area. Alternatively, where there was no evidence for permanent storage features either within or separate from structures, it was considered that there would at least have been a moderate amount of more ephemeral storage and, therefore, the formula for no storage was disregarded (i.e. Netiv Hagdud). In addition, this formula was disregarded where a substantial amount of upper storey residential floor area may have been used to access storage units or rooms on the lower floor (i.e. Beidha Subphase C2 and Basta).

An additional benefit of this method is that it is the only one that directly calculates dwelling unit size. However, estimates reflect the average of the maximum number of 1.65 m and 1.83 m tall adults that could sleep facing inwards within a structure. As such, it is possible that there may have been fewer people than estimated depending on the composition of the dwelling unit, use of residential floor area for animals or other factors affecting use of space that have not been accounted for within the formulae. Alternatively, there may have been more people than estimated if people were not concerned with conforming to this particular sleeping pattern or depending on the organisation of space during sleeping hours. In addition, larger dwelling unit sizes than estimated may have been present depending on the stature of individuals. For example, if children were present, an estimate of three people (i.e. 3 adults) could alternatively reflect two adults and two children or even one adult and four very small children. Despite this issue, the measurement of maximum occupant capacity, factoring in spatial use requirements that would have been relatively uniform within dwellings (i.e. hearths, activity zones, storage and access routes), remains a valuable tool for producing estimates of co-resident group size and total population size, and provides multiple avenues for further research of population dynamics at both the household and site level.

A major avenue for investigation relating to the SPF not addressed in this analysis is the role of animals within PPN settlements. Widespread evidence for animal domestication occurs from the MPPNB. It is possible that domesticated animals occupied some of the built area. This could explain the high spherulite frequencies identified in Locus 20 at MPPNB ‘Ain Abu Nekheileh (see Section 7.1.8). Tvetmarken (2012) adapted Hemsley’s (2008) method, estimating maximum capacity of both humans and animals within the Neolithic built environment in the Zagros. The results indicated a potential correlation between reduced compartmentalisation and the accommodation of animals (mainly small herds of goats) within the built area (Tvetmarken 2012, p.197). Within PPN Levantine settlements, there is a general increase in compartmentalisation, explained as representing increased distinction between public and private areas and attempts to restrict access to and within interior space (Byrd 1994; Kuijt 2000). If reduced compartmentalisation is indeed an indicator of housed domesticated animals, then the built environment at Ba’ja may provide an interesting case study for exploring this.

Faunal evidence at Ba’ja suggests rearing of domesticated goats, which may have formed as much as 80% of the meat diet (von den Driesch *et al.* 2004). Ba’ja is situated within a small intra-montane basin (c. 1.5 ha), surrounded by steep cliffs and slopes, which may have been hazardous for unattended domesticated animals, especially at night or in poor weather conditions (Gebel 2003). In addition, the high altitude would have produced markedly cooler temperatures during winter. There is considerable variation in architectural forms between excavated areas at Ba'ja, with several structures in Areas C and D comprising large, non-compartmentalised roofed floor areas (Bienert and Gebel 2004). It is plausible that domesticated animals were kept within these areas, particularly during the night. Examination of evidence (i.e. spherulites) for the potential use of built area for housing domesticated animals could further help refine the SPF and provide additional avenues for exploring the relationship between humans and animals within these settlements.

10.2.2 Bayesian chronological modelling of radiocarbon dates for reconstructing structural contemporaneity values

A major component of reconstructing accurate population size estimates is the ability to account for structural contemporaneity. This is based on the recognition that all structures identified in the archaeological record may not have been in simultaneous use, even if assigned to the same building phase (Kuijt 2008a). In previous studies, structural contemporaneity values for PPN settlements are not generally proposed or sufficiently justified. In this investigation, contemporaneity values are derived by dividing building use-life by phase length, as proposed by Varien *et al.* (2007). The major contribution of the current research relates to the use of Bayesian chronological modelling of radiocarbon dates to establish span estimates for building use-life and phase length.

Bayesian chronological modelling is becoming commonplace in archaeological investigation, although the method is generally utilised to explore long term or major episodes and events using large radiocarbon datasets. By comparison, building use-life and phase length represent relatively short-term events and the quantity of radiocarbon dates relating to these events is usually small. Only a handful of dates exist for most PPN central and southern Levantine sites, with the largest collections sourced from PPNA WF16 (*n* dates = 46) (Wicks *et al.* 2016) and PPNA/B Jericho (*n* dates = 45) (Benz 2013). Unfortunately, information regarding context, sample material and pre-treatment is often omitted from publications and radiocarbon date databases reducing the number of reliable dates for chronological modelling. Further, post-depositional processes, the type of sample material and pre-treatment all create additional methodological problems.

Despite these issues, exploration of basic chronological modelling for Beidha (see Section 6.1.5) and several other villages (i.e. Gilgal I, Netiv Hagdud, Shkārat Msaied, Ghwair I, Wadi Hamarash I, ‘Ain Abu Nekheileh, Basta and Ba’ja) (see contemporaneity assessments for each site in Section 7.1) revealed the potential of this method for producing more precise chronological information than that based on archaeological, ethnographic and/or experimental research alone, even with small sets of radiocarbon dates (*n* dates per site = 3-17). Span estimates were produced via models constructed using the OxCal software (v.4.2.4) (Bronk Ramsey 2009).

Direct contemporaneity values were derived for eight of the 15 villages/village phases assessed at the micro-level (Table 10.1; Figure 10.2). A further six were assigned contemporaneity values based on values derived for sites with comparable architectural form and layout, and an assessment of archaeological evidence for building construction, superpositioning and abandonment. The contemporaneity value for Shkārat Msaied was based on a combination of modelling, comparative analysis and architectural assessment.

Contemporaneity values vary from around 60% (Netiv Hagdud and Basta) to 80% (Nahal Oren and Shkārat Msaied). Directly derived values for sites that demonstrate similar characteristics to PPNB/PPNC ‘Ain Ghazal (i.e. Ghwair I and Beidha Subphase C2) compare well with Rollefson and Köhler-Rollefson’s (1989) proposed value of 80%. The reasonably limited range indicates that, in the absence of site-specific analysis, an average of around 70% may be suitable for central and southern Levantine PPN villages.

The contemporaneity values proposed in this investigation are based on basic modelling of limited numbers of radiocarbon dates. However, even this simple exploration highlights the great potential for this method to refine chronological information relating to short-term events and presents several avenues for more detailed methodological consideration. Possibly the greatest issue with modelling chronological information for PPN villages is the limited number of radiocarbon dates relating to the settlement or construction and abandonment of each phase and building. Samples are often sourced based on the quantity of the sample material in order to date a site to a specific time period, rather than strategically collected from points that enable span estimates. The collection of dates from targeted stratigraphic areas that have the greatest potential to reveal start, end and transition dates for short-term episodes will greatly improve the chronological resolution of these events.

The nature of the sample material is also important as this can distort the chronological resolution. Samples should preferably derive from short-lived plant materials, such as seeds and nuts (although these are more susceptible to post-depositional admixture), or from wood charcoal from twigs and juvenile branches (Bayliss 2009; Wicks *et al.* 2016). Structures are often constructed with large posts from tree species that survive several centuries. Sample material collected from these posts can create an 'old wood effect' resulting from both the age of the mature wood and from the use and re-use of trees that may have been felled for a considerable period (Wicks *et al.* 2016). Wicks *et al.* (2016, pp.13-14) explored an innovative methodology for accounting for the effect of old wood on chronological models at the PPNA settlement at WF16. An old wood offset was calculated from the difference between ages derived from mature and juvenile wood charcoal samples and an offset command was incorporated into the chronological model using the OxCal software. Unfortunately, the limited number of samples per phase and structure prevented calculation of old wood effects in this analysis.

Another major issue relates to the limited information regarding context, sample material and pre-treatment provided within publications and radiocarbon date databases. Precise information regarding context (i.e. phase, structure, feature or specific location within that structure/feature) is essential as this provides the prior chronological information required for constructing models and for removing statistically divergent dates from the model based on archaeological grounds (i.e. residual or intrusive material) (Bayliss 2009). Both context and sample material affect the degree of susceptibility to post-depositional impacts within the field and in radiocarbon dating laboratories (Brock *et al.* 2010). Elaboration of useful radiocarbon date databases, such as the Platform for Neolithic Radiocarbon Dates (PPND) (Benz 2013) and the radiocarbon CONTEXT database (Böhner and Schyle 2008) will facilitate reconstruction of more informative models.

Table 10.1. Contemporaneity values for central and southern Levantine PPN villages.

Site	Structural contemporaneity (%)			
	Modelled estimate	*Combination*[a]	*Indirect estimate*[b]	*Justification*
Netiv Hagdud	60			
Beidha (A1)	71.43			
Beidha (A2)	75			
Beidha (B2)	71.43			
Ghwair I	77.78			
‘Ain Abu Nekheileh	65			
Beidha (C2)	77.78			
Basta	60.47			
Shkārat Msaied		80		Modelled value (90.39%) considered too high; reduced based on comparable sites Beidha A1, A2 and B2
Nahal Oren			80	Compared to Beidha A1, A2, Shkārat Msaied: relatively high density, thick-walled, curvilinear structures; limited (Nahal Oren)/some (el-Hemmeh) superpositioning and abandonment
El-Hemmeh (PPNA)			75	
Gilgal I			60	Compared to Netiv Hagdud: relatively low density, thinner-walled, curvilinear structures; some superpositioning and abandonment
Wadi Hamarash I			78	Compared to Beidha C2 and Ghwair I: agglomerated rectilinear architecture, considerable remodelling and reconstruction; limited superpositioning or abandonment
El-Hemmeh (LPPNB)			78	
Ba'ja			78	

[a] Based on a combination of modelled spans and structural contemporaneity estimates derived for comparable sites.
[b] Based on structural contemporaneity estimates derived for comparable sites.

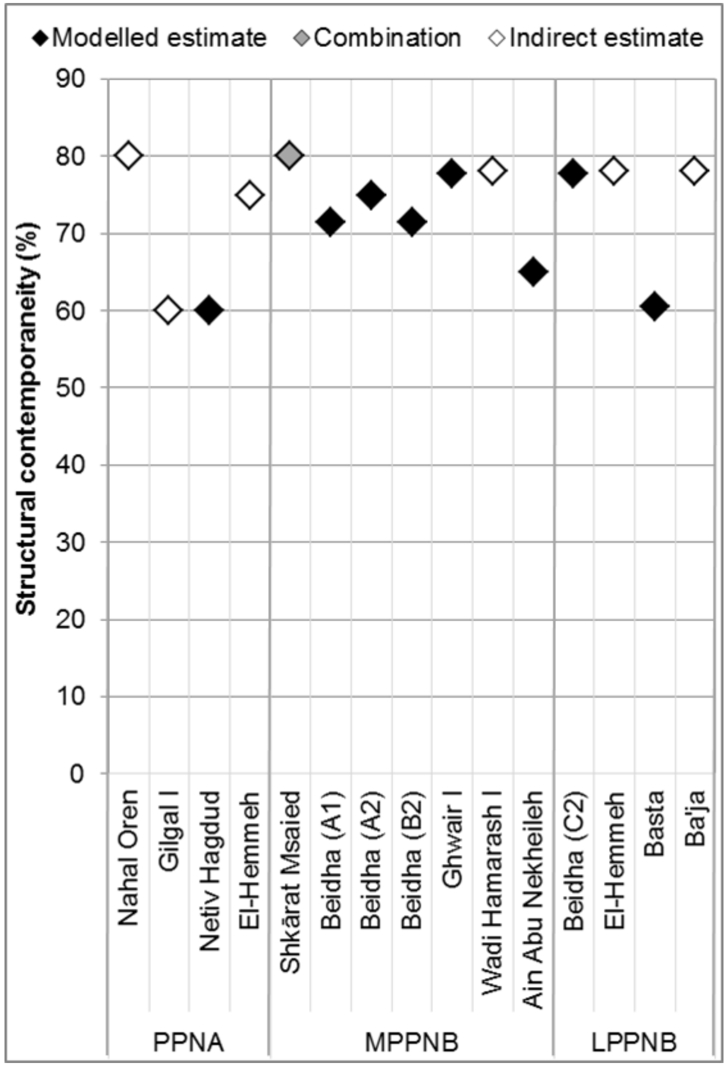

Figure 10.2. Contemporaneity values for central and southern Levantine PPN villages.

10.2.3 The proposed classification system

In order to extrapolate micro-level data for systematic application to all central and southern Levantine PPN villages in the database, a standardised site type classification system is required. Although classification does not reflect the full extent of variability in site layout and organisation, it is a useful analytical and organisational tool for systematically investigating large databases by dividing sites into mutually exclusive and comparable types (Gorodzov 1933, p.99; Adams 1988, p.43; 2009, p.138; Hörr *et al.* 2009, p.1).

For the purposes of estimating population parameters, site type classification was based on two main morphological characteristics that should be relatively easy to identify in the archaeological record: (1) predominant architectural form (i.e. curvilinear or rectilinear) and (2) a site size category (i.e. small, large or very large). The decision to classify sites using these two main characteristics was based on several factors. Firstly, architectural remains are often the focus of excavation programs and site plans depicting architectural features are virtually a ubiquitous output of all excavations. Secondly, there is a general recognition of differences in social organisation between settlements of different sizes and architectural forms (Flannery 1972; 2002; Wiessner 1982; Saidel 1993; Bar-Yosef 1998; Finlayson *et al.* 2011; Rollefson and Kafafi 2013). Thirdly, cross-cultural analyses of modern settlements and archaeological sites reveal strong positive correlations between settlement size and population size (Naroll 1962; Wiessner 1974; Aurenche 1981; Kramer 1982; Wossinik 2009). Finally, the use of two relatively easily discernible characteristics produces a basic classification system that can be routinely adopted by archaeologists.

Discriminant function analysis (DFA) of five potential classification schemes based on these two main attributes revealed that predominant architectural form contributes more to the classification system than site size (see Section 8.4). However, as a two type classification system was considered too broad to account for the considerable differences between sites of different sizes, a five type classification system including all size categories was considered most suitable. The final site types include (1) small and (2) large villages with predominantly curvilinear architecture; and (3) small, (4) large and (5) very large villages with predominantly rectilinear architecture.

The classification system proposed is an “open” system that can be refined by micro-level analyses of additional sites (Adams 1988, p.52). An increase in the number of cases (i.e. sites) will enable more comprehensive statistical analyses, particularly relating to the use of DFA for predicting site type (Burns and Burns 2008; Kovarovic *et al.* 2011) and analysis of variance (ANOVA) for identifying significant differences in the values of variables (i.e. people per dwelling) between site types (Drennan 1996; VanPool and Leonard 2011). This will facilitate reconstruction of more precise site type constants and formulae.

10.2.4 The new formulae for estimating PPN village population size

Universal and site type allometric growth formulae were developed to enable future reconstruction of central and southern Levantine PPN village population sizes based on estimated total site extent (see Section 9.7). Allometric growth formulae were created based on the recognition of strong positive cross-cultural correlations between population size and settlement size (Naroll 1962; Nordbeck 1971; Wiessner 1974; Aurenche 1981; Kramer 1982; Wossinik 2009) and the ability for scaling exponents to depict (and calculate) the relationship between population size and settlement size more precisely than population density coefficients. The proposal of minimum, mean and maximum formulae for each site type, with mean formulae correlating to mean structural density, allows consideration of building density in the final estimate. In addition, application of the range of formulae produces ranked population sizes that can be used to explore the relationship between conservative and more extreme group sizes and other demographic and environmental factors.

The scaling exponents achieved in this investigation provide some interesting comparisons. Those obtained for Site Types 1, 2, 4 and 5 range from 0.8638 to 1.0111. The universal scaling exponents range from 0.9256 to 0.976. These exponents fall within the range proposed by Wiessner (1974) for village settlements (b = 1) and Naroll (1962) for villages undergoing urbanisation (b = 0.84195), though they are generally closer to the former. These results, therefore, appear to support both Naroll's (1962) and Wiessner's (1974) original conclusions regarding village scaling exponents.

Scaling exponents for Site Type 3 are considerably lower (0.4768-0.6105). These exponents are more consistent with those derived from urban settlements (b = 2/3) (Nordbeck 1971; Wiessner 1974). In addition, the initial growth index range for Type 3 sites (a = 237-324) is considerably lower than those of other site types (min a = 300-438; max a = 628-825). These lower constants reflect the lower estimated population size relative to settlement size within Type 3 sites due to comparatively low proportions of (1) residential floor area in built floor area and (2) contemporaneous residential floor area in assessable area. Type 3 sites assessed at the micro-level (Wadi Hamarash I and Beidha Subphase C2) display distinctly different characteristics to most other sites with rectilinear architecture. These are compact and relatively well-structured settlements with well-defined, multi-storey, residential units, large non-residential structures, large and clearly planned open areas designated for communal activities and clear access routes. Although other site types with rectilinear architecture (Types 4 and 5) have combinations of these characteristics, these are generally more haphazardly structured.

Of the 106 villages and village phases assessed in this investigation, only three were assigned to Site Type 3, reducing the ability to make meaningful conclusions regarding this site type. There are almost certainly additional Type 3 sites that have been erroneously assigned to Type 4 due to publication of inflated total site extent estimates or due to the site extent threshold applied in this investigation (Type 3 - small: ≤ 0.5 ha; Type 4 - large: 0.6-6 ha). For example, Type 4 site Ghwair I demonstrates more similarities in structure and layout to Type 3 sites than Type 4 sites and was, indeed, re-classified from a Type 4 to a Type 3 site via DFA (see Section 8.4). The recognition that structural layout is related to site type was partially incorporated into the final formulae by equating mean structural density to the mean formula. A site type classification system that is additionally based on structural layout would be beneficial. However, given the minimal extent of excavations at most sites, this is not an easily discernible attribute and would reduce the ability for systematic application of the formulae.

The formulae proposed in this investigation can easily be systematically applied to central and southern Levantine PPN villages and have potential for application to comparable sites in other periods and regions. However, there are some underlying issues that require consideration. The estimation of total site extent is highly problematic for several reasons (Kuijt 2000; Verhoeven 2006; Kuijt 2008a; Goring-Morris and Belfer-Cohen 2008). For example, site size is difficult to determine from surface scatters, as this requires detailed analysis of post-depositional processes, and, unfortunately, due to the time and financial constraints of many projects, large scale open plan excavation is not viable. In addition, there is a tendency to overestimate site extent, particularly where sites exhibit rectilinear architecture, or to publish maximum site extents that incorporate several occupation episodes. If published estimates are to be used, these must be critically assessed, and additional field and desk-based research should be conducted to more accurately delineate habitable areas. This could be achieved through aerial photography, sub-surface detection techniques and/or the use of geographical information systems to examine topographical setting.

A further issue with the application of the formulae to site extent is that this method produces the same population estimates for sites of the same size. This is one of the major problems with the current commonly used method (i.e. application of a density value to site extent). However, the site type formulae proposed in this investigation result in different population estimates for many sites of the same site extent by considering the relationship between site size and architectural features.

A final issue with applying these formulae relates to the potential for compounding errors. The final formulae are derived from the regression of population estimates against estimated total site extent. These population estimates were originally reconstructed from site extent and constants derived from micro-level analysis. As such, the final formulae are twice removed from the original micro-level data. Ideally, the formulae should be reconstructed from micro-level estimates. However, the limited number of sites available for micro-level analysis has prevented this. This may be achievable in future with more detailed assessment of additional sites.

10.3 Group size thresholds

Population estimates reconstructed in this investigation were assessed against the available archaeological evidence to determine whether previously hypothesised group size thresholds (see Table 4.8) may be applicable to PPN central and southern Levantine villages and to establish additional potential thresholds specific to this period and region (Figure 10.3). The proposed thresholds are based on the assumption that population size is the major contributing factor in cultural evolution. This is problematic as there are clearly various interrelated factors that induce cultural evolution. The thresholds proposed here are, therefore, highly speculative and tentative, though do provide potential insights into the relationship between demographic parameters and cultural evolution during this period.

The proposed group size thresholds depend on the validity of the population estimates produced in this investigation and the availability of archaeological evidence for developmental processes. As such, additional excavations and published information that enable refinements of these will facilitate the production of more precise and informative group size thresholds in future.

Group size thresholds apply to the initial transition to, or adoption of, a specific stage or process. Once a developmental stage has been reached, it is expected that this development would be retained within smaller subsequent PPN settlements based on the notion of cumulative cultural evolution provided that sufficient numbers of inhabitants exist to maintain these processes (White 1959; Shennan 2001; Henrich 2004; Vaesen 2012; Castro and Toro 2014). The thresholds explored in this investigation relate to three major categories of human social development during the NDT: changing subsistence practices; the introduction of mechanisms for reducing scalar stress and promoting social cohesion; and the emergence of social complexity.

10.3.1 Changing subsistence practices

Increased group sizes require developments in subsistence strategies, particularly when groups decide to settle in a location permanently. The minimum previously hypothesised population size required for the transition to sedentism is around 25 people (Fletcher 1981; Binford 2001; Kuijt and Goring-Morris 2002, p.369; Bandy 2010, p.31). This threshold is based on the average number of nuclear families suggested to comprise early sedentary communities (i.e. perhaps 5-10 nuclear families) (Goring-Morris and Belfer-Cohen 2008, p.274) and the minimum labour force required to sustain the population (Binford 2001, p.438). This investigation assessed only sites that could be considered sedentary settlements (i.e. villages). The lowest population estimate derived in this investigation (Nahal Oren: P = 25-45) parallels this threshold range, indicating that this may be a suitable threshold for inferring initial sedentism in PPN communities. However, permanently settled communities of smaller sizes may not have been excavated due to a lack of targeted investigation or a lack of visibility.

The adoption of farming practices (i.e. the cultivation of wild plants) is expected to occur within settlements of at least 50 people, based the minimum labour force required for the primary mode of subsistence (Binford 2001, p.438; Drennan and Peterson 2008). The earliest villages with evidence for farming practices occur during the PPNA, where wild plants were cultivated by small communities estimated at a minimum of 80 people (i.e. Bir el-Maksur and Zahrat adh-Dhra'2). Intensified cultivation of wild grains occurs during the EPPNB, with the smallest settlement providing evidence for this estimated at a minimum of 150 people (Mujahiya) (Gopher 1990). Based on the estimates produced in this investigation and the available archaeological evidence, tentative group size thresholds of at least 80 people could be suggested for the initial transition to farming practices during the PPNA and at least 150 people for intensified cultivation of wild plants during the EPPNB.

The adoption of a fully agro-pastoralist subsistence strategy is expected to occur within settlements of around 100 to 750 people (Fletcher 1981; Kuijt and Goring-Morris 2002). However, given the temporal variation in the introduction of domesticated plant and animal species and the intensification of practices relating to these, thresholds relating to agricultural and pastoral practices are perhaps better defined separately.

The earliest potential evidence for agricultural practices (i.e. farming of domesticated plants) has been identified at EPPNB Tell Aswad IB, estimated at a minimum of 300 people (Tanno and Willcox 2012; Chamel 2014). From the MPPNB, the majority of villages contain evidence for domesticated emmer, barley and einkorn, with villages estimated at a minimum of around 350 people exploiting a wider repertoire of domesticated plants, including lentil, chickpea and flax (i.e. Yiftah'el IV, 'Ain Ghazal, Jericho and Tell Aswad II) (Colledge and Conolly 2007; Weiss and Zohary 2011). Evidence for fig cultivation also occurs at MPPNB Tell Aswad II, estimated at a minimum of around 1,800 people (Stordeur and Jamous 2009).

The earliest evidence for culturally-controlled and/or potentially domesticated animals occurs during the MPPNB within villages estimated at a minimum of 80 people (Van Zeist and Bakker-Heeres 1985; Rollefson *et al.* 1993; Simmons *et al.* 2001; Henry *et al.* 2002; 2003; Henry and Albert 2004; Helmer and Gourichon 2008; Stordeur and Jamous 2009; Peterson *et al.* 2010; Gkotsinas and Karathanou 2013; Kinzel 2013; Makarewicz 2013; Martin and Edwards 2013). However, the smallest MPPNB village in this investigation with conclusive evidence for domesticated animals is Ghwair I, which was estimated at a minimum population size of 400 people (Simmons and Najjar 2006). Larger MPPNB villages demonstrate evidence for intensified pastoral practices involving the use of animals for meat and milk production (i.e. 'Ain Ghazal: P ≥ 1,500) (Makarewicz 2013) and the introduction of domesticated pig and cattle (i.e. Tell Aswad II: P ≥ 1,800) (Helmer and Gourichon 2008). During the LPPNB, even the smallest village (Beidha Subphase C2: P = 140-220) has yielded evidence for domesticated animals, although evidence suggests predominant reliance on hunted meat sources. This is consistent with current theory indicating a major LPPNB shift towards subsistence strategies heavily dependent on domesticated plant and animals (Kuijt and Goring-Morris 2002; Makarewicz 2009; 2013).

Based on this evidence, three major group size thresholds relating to agro-pastoralist subsistence strategies involving domesticated plants and animals are proposed for the PPN central and southern Levant:

1. The initial adoption of agro-pastoralist practices during the MPPNB (P ≥ 400).
2. Intensified agro-pastoralist practices during the MPPNB (P ≥ 1,500).
3. Predominant reliance on an agro-pastoralist subsistence strategy during the LPPNB (P ≥ 550).

10.3.2 Reducing scalar stress and promoting social cohesion

Strategies for mitigating the effects of scalar stress are hypothesised to occur when populations reach around 150 people (Chagnon 1980; Kosse 1990; Bowser 2000; Kuijt and Goring-Morris 2002; Dunbar 2003). Alberti (2014, p.13) identifies several potential strategies, including fissioning into smaller groups; engaging in activities for creating community cohesion (i.e. the introduction of ritual practices and communal food-related activities); the building of integrative facilities; reshaping of decision-making processes; and the development of leadership roles.

Community fissioning into smaller sub-units is evident within some of the larger PPNA villages (P ≥ 160) (i.e. Gilgal I, Netiv Hagdud, Jericho), which contain dwellings associated with annexes that could be interpreted as representing emergent household economic units (Kenyon 1981; Bar-Yosef *et al.* 1991; 2010a; 2010b). The prevalence of sub-floor burials and evidence for dwelling-based specialist activities within EPPNB dwellings, particularly at Motza VI (P = 150-330) and Mujahiya (P = 150-330) (Gopher 1990; Khalaily *et al.* 2007), may reflect the increasing independence of these household units. It has been suggested that the MPPNB represents a widespread shift towards house -based societies based on evidence for more formalised and restricted access to dwellings, greater compartmentalisation within dwellings, and widespread evidence for dwelling based food- and production-related activities (Gebel 2002; Kuijt and Goring-Morris 2002). These developments are present within all MPPNB villages assessed in this investigation (P ≥ 80).

Sectoring of the community into neighbourhoods, with open areas between clusters of structures, can help to mitigate the effects of social crowding by reducing overall population density. This segregation is apparent within larger PPNA villages (P ≥ 160) (i.e. Gilgal I, Netiv Hagdud and Jericho), with neighbourhoods potentially occurring within most MPPNB villages (P ≥ 80) (i.e. Beidha, Shkārat Msaied, Wadi Hamarash I and Ghwair I) (Simmons and Najjar 2006; Byrd 2005a; Kinzel 2013; Sampson 2013a). Clearly defined neighbourhoods or sectors with variable structural layout and distribution are apparent throughout the LPPNB (i.e. ‘Ain Ghazal, Ba’ja and Basta) (Hermansen and Gebel 1996; Rollefson 1998a; Nissen 2006). Community segmentation is highly visible in larger PPNC villages (P ≥ 1,000), where large walls dissect some settlements (i.e. Atlit-Yam and ‘Ain Ghazal) (Goring-Morris and Belfer-Cohen 2008).

Innovative architectural developments may also reflect attempts to reduce scalar stress caused by social crowding (Kuijt 2000). The transition to rectilinear architecture appears to have occurred mainly during the EPPNB and is visible within settlements estimated at a minimum of around 300 people (i.e. Horvat Galil, Tell Qarassa and Mishmar Ha’emeq) (Hershkovitz and Gopher 1988; Ibañez *et al.* 2010; Bocquentin *et al.* 2011). Rectilinear architecture enables more efficient use of space and is easier to compartmentalise, increasing the ability for control and privacy despite higher population density (Kuijt 2000). Architectural innovations, including multi-storey structures and sub-floor channels for water or air during the MPPNB (i.e. Wadi Hamarash I: P ≥ 150) (Sampson 2013a), would have further mitigated the effects of scalar stress within these high density settlements by augmenting space and improving conditions within structures.

Whilst these strategies effectively split communities into more manageable groups and helped communities cope with high density living, other strategies promoted social cohesion by creating a collective cultural conscience. In the earlier PPN, the maintenance of largely egalitarian, hunter-gatherer subsistence strategies would have promoted a sense of community, particularly within smaller villages where face-to-face interaction could be sustained between all members of the society (P ≤ 400) (Kosse 1990, p.284). However, in larger villages, formal strategies would have been required to create and promote collective interests. A potential strategy for this is the formalisation and elaboration of ritual practices.

Ritual practices are prevalent within all villages from the PPNA. However, the construction of ritual buildings and the manufacture of ritual and symbolic items appear to be more elaborate and more formalised within larger PPNA villages (P ≥ 160) (i.e. Gilgal I and Jericho) (Kenyon 1981; Bar-Yosef *et al.* 2010a; 2010b). Ritual and symbolic features developed throughout each subsequent period. Major advancements occurred within larger MPPNB villages (P ≥ 1,500) (i.e. 'Ain Ghazal, Jericho and Tell Aswad II), which contained extensive collections of intricate and expertly crafted ritual and symbolic items (Kuijt and Chesson 2005); and in larger LPPNB villages (P ≥ 500), which contained evidence for more elaborate ritual practices, including greater variety in grave goods, more detailed figurines and the insertion of infant bones into wall niches (Kuijt and Chesson 2005).

An assessment of the population estimates achieved in this investigation and the available archaeological evidence indicates that the threshold of 150 people often proposed as the critical group size at which communities introduce mechanisms for reducing scalar stress and promoting social cohesion may be applicable to several developments within central and southern Levantine PPN villages (Chagnon 1980; Kosse 1990; Bowser 2000; Kuijt and Goring-Morris 2002; Dunbar 2003). These include:

- sectoring of the community into potential household units and dwelling clusters, and the adoption of more formalised ritual practices during the PPNA;
- the increasing independence of household units during the EPPNB;
- the innovation of multi-storey rectilinear architecture during the MPPNB; and,
- well-established household economic functions and clearly defined neighbourhoods during the LPPNB.

Other potential thresholds relate to the transition to rectilinear architecture during the EPPNB (P ≥ 300) and the construction of sub-floor channels for water or air during the LPPNB (P ≥ 550); substantial efforts to segment the community during the PPNC (P ≥ 1,000); and the adoption and production of increasingly elaborate and formalised ritual practices and symbolic items during the MPPNB (P ≥ 1,500) and LPPNB (P ≥ 500).

10.3.3 Emerging social complexity

There is considerable overlap between the archaeological evidence for scalar stress reduction strategies and the evidence for emerging social complexity. More complex social structures are hypothesised to occur within settlements of at least 250 people (Forge 1972; Kosse 1990), with authoritative figures occurring within settlements of at least 500 people (Naroll 1956; Kosse 1990). Social differentiation within almost all PPN villages is potentially evidenced by intra-site variations in structural forms and associated annexes, reflecting segregation of dwelling units and differential engagement with household based food- and production-related activities. This differentiation is most distinct from the MPPNB, at sites such as Wadi Hamarash I and Ghwair I (P ≥ 150), which demonstrate considerable intra-site variations in structural layout and organisation.

Social differentiation is also potentially indicated by variable distributions of items that may have been utilised for individual or group identity, such as incised pebbles, objects of personal adornment, items made from exotic materials, and ritual and symbolic items, including figurines (Wright and Garrard 2003, p. 277; Bar-Yosef 2005; Kuijt and Chesson 2005; Edwards and House 2007). Perhaps the clearest evidence for social differentiation comes from EPPNB villages of at least 150 people, where human burials demonstrate increasingly variable association with grave goods and structures (i.e. Motza VI and Tell Qarassa) (Khalaily *et al.* 2007; Ibañez *et al.* 2010), including some bodies placed on platforms at Tell Aswad IB (Stordeur and Khawam 2008; Chamel 2014).

A major aspect of complex societies is labour differentiation, which stems from increasingly specialised knowledge. During the EPPNB, specialist knowledge is indicated by the widespread adoption of naviform core technology and the use of lime plaster within the majority of sites (P ≥ 80); and the transition to rectilinear architecture in larger villages (P ≥ 300). Intensified and diversified specialist activities occur throughout the MPPNB, including major developments in agro-pastoralist practices; large-scale bead production for export (Berna 1995; Fabiano *et al.* 2004); increased use of imported materials for items of personal adornment; large-scale manufacture of lime plaster for use in architecture and in ritual and symbolic contexts; and innovative architectural developments, including the construction of multi-storey structures and sub-floor channels (i.e. Wadi Hamarash I: P ≥ 150). During the LPPNB, the range of specialist activities increased, including large-scale sandstone ring and bead production at most sites (Byrd 2005a; Kinzel 2013); the construction of water barrages at Wadi Badda (P = 370-680) (Fujii 2007); and possible intentional irrigation at Ba'ja (P = 580-610) (Kinzel 2013) and el-Hemmeh (P = 530-800) (White 2013). Innovation in water technology also occurred during the PPNC with the construction of wells at Atlit-Yam (P = 1,090-2,040) (Galili *et al.* 2004). These specialist techniques required a high degree of technical knowledge, indicating potential labour diversification and the capacity for individuals and households to enhance their own skills, and potentially their own wealth and status.

Unequal distribution of these skills, wealth and status may have led to concentrations of power, giving rise to individuals with decision-making and authoritative roles. Such individuals may have been present as early as the PPNA, as evidenced by the construction of the tower and village wall at Jericho (P = 740-1,650) (Kenyon 1956; 1981), which would have required an organised work force and some degree of planning and management. Additional evidence for the emergence of authoritative individuals occurs during the EPPNB, with special mortuary treatment potentially reserved for individuals with higher status at Tell Aswad IB (P = 300-660) (Stordeur and Khawam 2008; Chamel 2014). Authoritative individuals would also have been required to disseminate the increasingly specialist and technical knowledge to younger generations.

Authoritative individuals may also have emerged from the increasing focus on ritual activities. Many cultures demonstrate a considerable overlap in religion and politics, with ritual figures undertaking divinely sanctioned ritual activities as a means of social control (Watts *et al.* 2016, p.231). The increasingly formalised ritual practices and space designated for such activities within PPN villages suggests the growing importance of ritual practices and centralised control of these activities. This is particularly evidenced by the tower construction at PPNA Jericho (P = 740-1,650) (Kenyon 1956; 1981); the large ritual building associated with a burial ground at EPPNB Mishmar Ha'emeq (P = 320-750) (Bocquentin *et al.* 2011); and the general presence of large, centrally-located, distinctive, non-residential structures from the MPPNB (Rollefson *et al.* 1993; Rollefson and Kafafi 1997; Byrd 2005a; Kinzel 2013; Sampson 2013a). Increasing competition between households, social differentiation, increasingly specialist knowledge and the presence of authoritarian figures are all characteristics of an increasingly stratified community.

It has been hypothesised that settlements with populations greater than 1,500 people may have produced rival authority figures or groups, which could have initiated political stratification (Alder 1990). Possible evidence for this includes the segmentation of villages into neighbourhoods of potentially competitive or rival groups from the MPPNB (i.e. Wadi Hamarash I and Ghwair I: P ≥ 150). However, the most substantial evidence for this is the dissecting of villages into sectors in the PPNC (i.e. Atlit-Yam and ‘Ain Ghazal: P ≥ 1,090).

An assessment of the population estimates produced in this analysis and the available archaeological evidence for social complexity has revealed several potential group size thresholds:

1. Social differentiation may have occurred within all PPN villages, but is particularly evident from the EPPNB, within villages of at least 150 people, as indicated by increasingly specialist knowledge and increasing independence of household units.
2. Diverse specialist activities and highly innovative technological developments occur in all villages from the MPPNB, with major developments in water technology during the LPPNB (i.e. water barrages: P ≥ 350 and intentional irrigation: P ≥ 550) and PPNC (i.e. water wells: P ≥ 1,000) (Mahasneh 1996; Fujii 2007; Kinzel 2013; White 2013).
3. Authoritative individuals may have been present at PPNA Jericho (P ≥ 750), though more plausibly emerge during the EPPNB within villages of at least 300 people.
4. Rival authoritative individuals may have occurred during the MPPNB (P ≥ 150), though the most substantial evidence for this occurs during the PPNC (P ≥ 1,000).

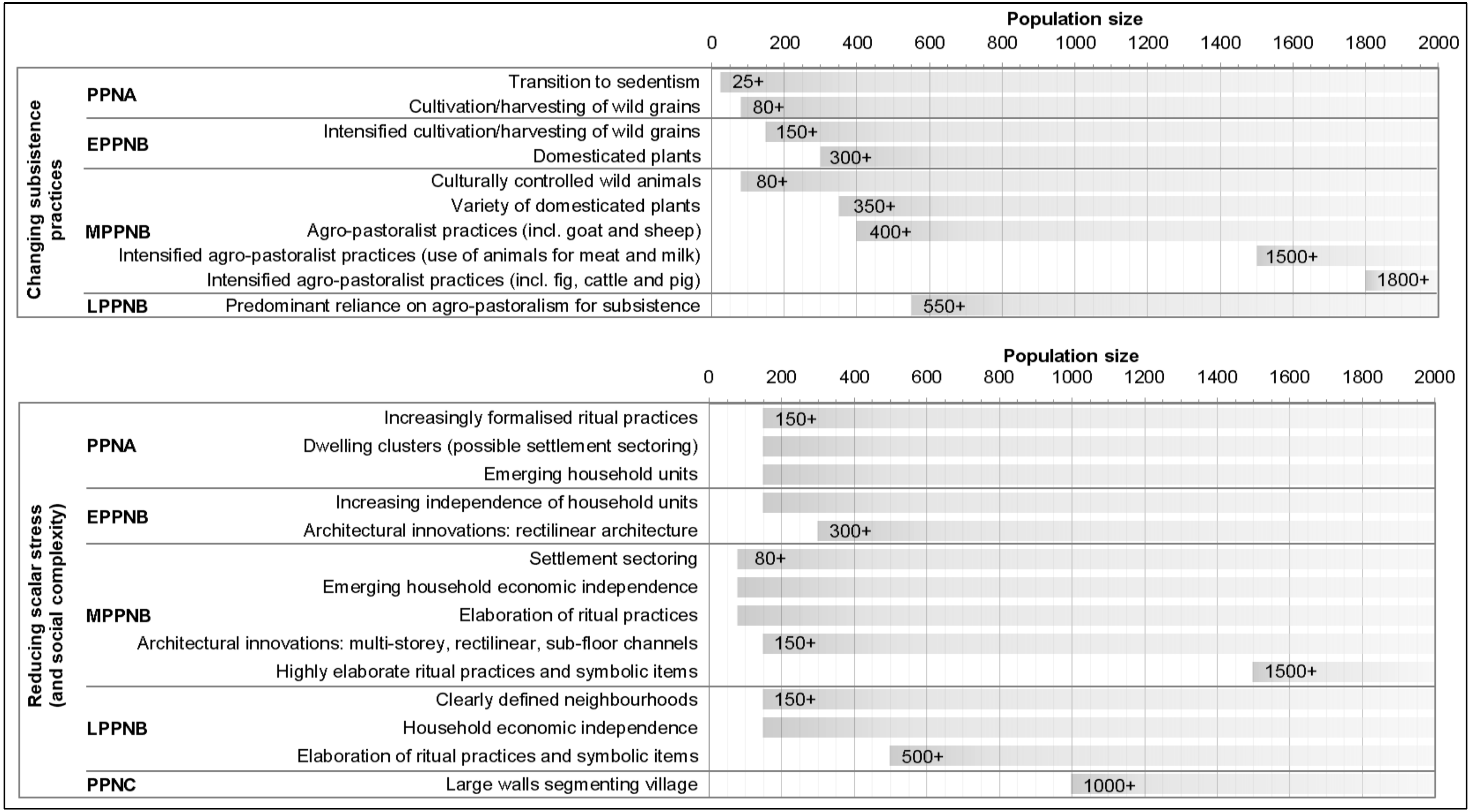

Figure 10.3. Potential group size thresholds for PPN central and southern Levantine villages.

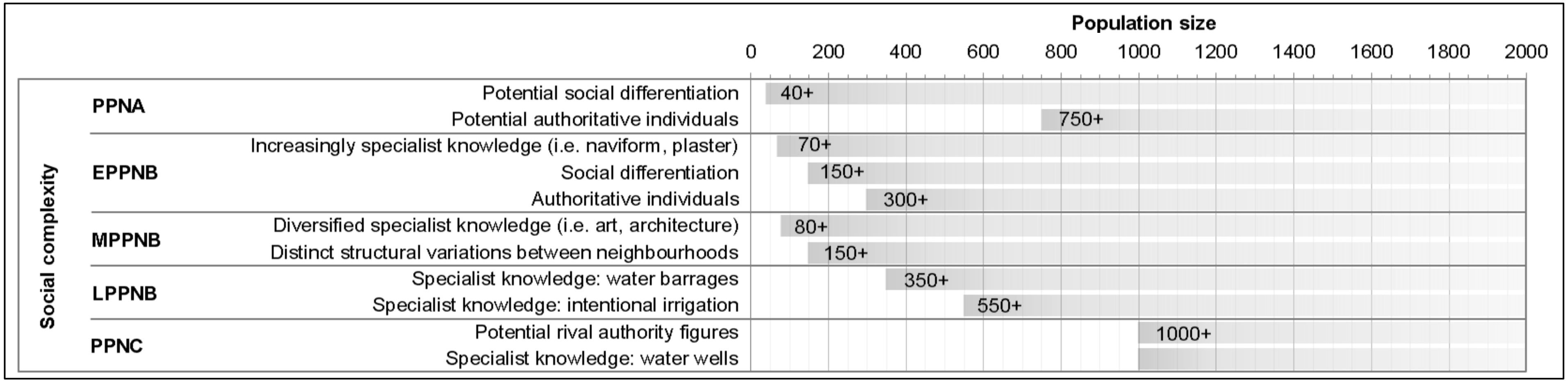

Figure 9.3. Potential group size thresholds for PPN central and southern Levantine villages (continued).

10.4 Summary

This chapter highlights the major theoretical and methodological contributions of this research and provides several avenues for further analysis. This investigation has re-assessed assumptions relating to dwelling unit size and composition, proposing four dwelling unit types each reflecting different social organisation: (1) very small dwelling units potentially forming a larger extended family group; (2) very small nuclear family dwelling units representing the emergence of household units; (3) larger nuclear family dwelling units representing increasing household economic independence; and (4) extended family units representing economically independent and competitive household units. The estimates achieved in this analysis indicate that settlements with curvilinear architecture comprise the first three dwelling unit types, while those with rectilinear architecture comprise the last two types only. It is not appropriate to assert that nuclear families formed the predominant dwelling unit within PPN settlements or to systematically apply ethnographically derived nuclear family sizes of five to six people, as is so often proposed (Sweet 1960; Wright 1969; Antoun 1972; Kramer 1979; 1982; van Beek 1982; Byrd 2002; 2005a). If methodologies are to employ dwelling unit sizes in reconstructions of PPN population estimates, greater effort must be taken to first ascertain dwelling unit composition by assessing residential architectural forms and features, and archaeological evidence for social organisation to determine potential co-resident patterns.

Assumptions and methods relating to settlement population density were also re-evaluated. To date, almost all estimates of PPN central and southern Levantine village populations have been based on the application of three standard ethnographically derived density values to total site extent (90, 150 and 294 people/ha) (Rollefson and Kohler-Rollefson 1989; Kuijt 2000; 2008a; Campbell 2009). This analysis highlighted several issues with this technique, the foremost of which were the resulting broad population estimate ranges and the apparent underestimation of population sizes of the majority of sites. This was particularly evident when population estimates based on the maximum density value resulted in apparently insufficient dwelling unit size estimates. Population density values re-calculated from population estimates achieved in this investigation generally ranged from around 400 to 750 people. If density is used to derive population size of central and southern Levantine PPN villages in future, it is proposed that these revised density values are used in place of the commonly utilised ethnographically derived values.

A major aim of this research was to explore more empirically and archaeologically-based methods for reconstructing PPN village populations without relying on the use of ethnographic comparatives. For micro-level analyses, the storage provisions formula

(SPF) presents the most empirically robust method for estimating population size by determining the maximum affordance of sleeping individuals within dwellings, factoring in common spatial elements. SPF estimates can be refined by examining archaeological evidence for the potential for storage within the residential floor area. Although this method has some underlying methodological issues (particularly relating to the use of adult sleeping space requirements), for which further work is proposed, it has the greatest potential of all of the methods explored in this analysis to produce accurate estimates of both dwelling unit size and population size without relying heavily on ethnographic assumptions and data.

Another major aspect of this research was to examine potential structural contemporaneity within PPN settlements. A technique was explored to reconstruct structural contemporaneity values based on estimates of building use-life and phase length derived from a combination of archaeological, ethnographic and experimental research, and Bayesian chronological modelling of spans of radiocarbon dates. This assessment produced contemporaneity values ranging from around 60% to 80%. An average value of around 70% is suggested for PPN central and southern Levantine villages in the absence of site-specific analysis. The basic analysis conducted in this investigation highlights the major potential of this method for refining chronological information relating to short-term episodes. However, due to issues with radiocarbon dates, the use of Bayesian chronological modelling for this purpose has not yet been widely explored.

In order to systematically produce population estimates for all PPN central and southern Levantine villages in this analysis, a site type classification system was produced. This was based on two major attributes that should be relatively easy to discern: predominant architectural form and a site size category. The five site types proposed were: (1) small sites with curvilinear architecture; (2) large sites with curvilinear architecture; (3) small sites with rectilinear architecture; (4) large sites with rectilinear architecture; and (5) very large sites with rectilinear architecture. This site type classification system was specifically developed for the purpose of estimating PPN village populations and constructed in such a way as to be easily applied and enhanced by researchers in future.

Universal and site type allometric growth formulae were developed for each of these site types to estimate minimum, mean and maximum population sizes based on estimated total site extent. Allometric growth formulae have greater ability to reflect the variable relationship between site size and population size than population density coefficients. The major issue with both methods for estimating population is the accurate estimation of site extent.

An assessment of population estimates achieved in this investigation together with the available archaeological evidence produced several potential group size thresholds relating to changing subsistence practices; mechanisms for reducing scalar stress and promoting social cohesion; and emerging social complexity. Major thresholds relate to the initial adoption of an agro-pastoralist subsistence strategy during the MPPNB ($P \geq 400$) and the predominant reliance on this strategy during the LPPNB ($P \geq 550$). Several developments equate to Dunbar's (2003) number of 150 people for the introduction of mechanisms for reducing scalar stress and promoting social cohesion, including initial community sectoring and formalised ritual activities during the PPNA; increasing household independence and the emergence of social differentiation during the EPPNB; multi-storey architectural innovation during the MPPNB; and well-defined neighbourhoods and independent household economic units during the LPPNB. These thresholds assume that population size is the major contributing factor to cultural evolution. The lack of consideration of other impacting factors is somewhat counteracted by focussing on the relatively restricted geographical and cultural context of the PPN central and southern Levant. There are clearly other factors that should be considered and it is hoped that the thresholds presented here provide a solid foundation for this further investigation.

11 Conclusion

The purpose of this investigation was to establish a more empirically and statistically robust method for estimating population parameters of central and southern Levantine PPN villages, and to produce a precise chronology of population parameters for this region in order to facilitate further research. A major objective of this research was to develop methods that were less reliant on ethnographic evidence. A comparison of the modern and prehistoric environmental context (Chapter 2) and an analysis of the major developments in subsistence, technology, architecture, ritual practices and social organisation throughout the PPN (Chapter 3) indicated that Southwest Asian villages are not suitable ethnographic comparisons for many PPN villages, particularly those with curvilinear architecture. Unfortunately, to date, almost all estimates of central and southern Levantine PPN village populations have been based on population density coefficients derived from ethnographic research in Southwest Asian communities (Jacobs 1979; Watson 1979; Kramer 1982; van Beek 1982; Bar-Yosef 1986; Rollefson and Köhler-Rollefson 1989; Kuijt 2000; 2008a; Ladah 2006; Campbell 2009) (see Section 4.3.1). The identification of numerous issues with this methodology, including the use of density values that were found in this investigation to be too low, justifies the complete revision of the pre-existing estimates, the underlying methodologies and related theories.

An examination of various methods for estimating population parameters highlighted several that are potentially suitable for application to early village settlements (Chapters 4 and 5). Six methods were selected for reconstructing population parameters at the micro-level (Chapters 6 and 7; Appendices B and C). Each of these methods employs a structural contemporaneity value derived from a combination of Bayesian chronological modelling of radiocarbon dates, and archaeological, ethnographic and experimental research of the building use-life of comparable structures. Of the six methods explored, the storage provisions formula (SPF) was considered the most robust and valid (see Sections 4.5 and 10.2.1). This method correlates residential floor area to maximum sleeping occupant numbers, factoring in three different amounts of personal annual residential storage. One of the major benefits of this method is that it relies almost exclusively on empirical archaeological data.

Data was extrapolated from micro-level analyses to systematically estimate the population size and density of all sites in the central and southern Levantine PPN village database (Appendix E.1). To achieve this, a site type classification system incorporating five categories was established, enabling both site type and universal constants to be reconstructed for variables utilised in systematic methodologies (i.e.

people per dwelling, residential floor area per person and people per hectare) (see Chapter 8).

Seven methods were selected for systematic application to the PPN village database (Chapter 9; Appendix E.2). These methods produced additional demographic data (i.e. the total number of contemporaneous dwellings or the total contemporaneous residential floor area) for each site. The three methods considered most valid for reconstructing the final estimates include the storage provisions formulae (SPF); the settlement population density coefficient (SPDC) method based on density estimates produced in this investigation; and the allometric growth formula (AGF2) using Wiessner's (1974) scaling exponent for village settlements (b = 1) and initial growth indices also produced in this investigation. The final estimate ranges were used to create site type and universal allometric growth formulae to estimate the minimum, mean and maximum population of central and southern Levantine PPN villages, with mean structural density per site type equating to the mean formula (see Section 9.7).

An assessment of dwelling unit sizes produced in this investigation and current theory relating to dwelling unit size and composition during the PPN highlighted variable types of dwelling unit (see Section 10.1.1). Finally, population size estimates were assessed against the available archaeological evidence to explore pre-existing and additional hypothesised group size thresholds relating to changing subsistence practices; mechanisms for reducing scalar stress and promoting social cohesion; and emerging social complexity (see Section 10.3).

11.1 Further work

This investigation provides several avenues for further research, outlined below.

1. A re-evaluation of population density values (people/ha) and the relationship between density and early village development during the NDT:

The population density values produced in this investigation (mean: 400-750 people/ha) are considerably higher than the range commonly proposed for Neolithic villages (90-294 people/ha). Investigation of additional PPN villages is required to determine whether these high densities were characteristic of this period and, if indeed they are, to explore the social and technological developments that enabled people to live in such high density settlements during this period.

2. A refinement of the storage provisions formulae (SPF) by using estimated Neolithic male and female stature:

The SPF is currently based on the lower and upper end of modern average adult height ranges of 1.65 m and 1.83 m, with average personal sleeping space allocations of 1.24 m^2 and 1.77 m^2, respectively (Hemsley 2008, p.82). Skeletal analysis has revealed that modern people are taller than Neolithic people. The SPF could, therefore, be refined by replacing the modern height estimates with average Neolithic height estimates. Hershkovitz and Gopher (2008, p.455) reconstructed human stature during the Neolithic of the southern Levant, estimating mean heights of around 164.5 cm for males and around 154.5 cm for females.

3. A refinement of the SPF to account for the presence of children:

The SPF is currently based on adult population only. However, children would certainly have been present and need to be factored into the calculations, though in a manner that does not make assumptions regarding dwelling unit composition. One method would be to consider the proportion of the population that would have comprised children. Hershkovitz and Gopher (1990) and Eshed *et al.* (2004, p.320) assessed skeletal samples from the Neolithic southern Levant, identifying that around 25% of the skeletal population comprised children. In an analysis of the Kfar HaHoresh skeletal remains, Eshed *et al.* (2008, p.95) identified that 31.5% of the burial population comprised children of less than 15 years. An average of around 27% could be used to refine the SPF method. However, the ratio of children to adult remains in the skeletal population may not represent the living population due to variable mortuary treatment, the greater potential for taphonomic impact on immature bones, and, perhaps most importantly for early sedentary communities, a high infant mortality rate. Infant mortality rates in pre-industrial populations have been averaged at around 30% to 50% (Hassan 1981, p.138), with mortality rates in PPN populations in the southern Levant estimated at around 16.5% before the age of five (Hershkovitz and Gopher 2008, p.446) and up to 50% before the age of 20 (Smith *et al.* 1984). These would need to be factored into estimates of the proportion of children in the living population.

4. A refinement of the SPF to account for the use of built area for domesticated animals:

It is plausible that some built area was designated for housing animals within settlements, at least from the MPPNB when domesticated animals became more prevalent. This would potentially reduce the amount of available residential floor area used in SPF calculations, resulting in lower population estimates. An examination of evidence for the use of built area by animals could help identify structures or specific areas used for this purpose. This evidence might include high spherulite frequencies (Henry *et al.* 2003; Henry and Albert 2004); a lack of internal compartmentalisation of structures (Tvetmarken 2012); sub-floor channels that might suggest drainage; and lime plaster floors that would have been hard enough to support the weight of animals and also allow for drainage. Identification of areas used for animals would allow exclusion of these areas from estimates of available residential floor area, thus refining population estimates based on the SPF method.

5. Bayesian chronological modelling of radiocarbon dates to estimate phase length and building use-life:

An increased number of radiocarbon determinations is required in order to reconstruct more informative chronological models (including adjustments for old wood effects) to produce more precise estimates of phase length and building use-life for reconstructing structural contemporaneity values. Elaboration of radiocarbon date databases (i.e. the PPND and the radiocarbon CONTEXT database) would be useful. In addition, further determinations should be produced from sample material strategically collected from contexts relating to the start, transition and end dates for these episodes.

6. Additional micro-level analysis for refining the site type classification system, site type constants and the final formulae:

An increase in the number of sites assessed at the micro-level would enable more comprehensive statistical analyses than those achieved with the small dataset used in this analysis (*n* cases = 15). For all site types, except Type 1 (*n* = 7), the number of cases assessed at the micro-level was three or fewer. Additional cases would enhance the database of estimates required to refine the site type classification system and to produce more precise constants. In addition, the final formulae proposed for estimating central and southern Levantine PPN village populations would be more accurate if directly developed from micro-level analyses.

Ideally, additional research will be conducted on further PPN villages within the Levant and comparable settlements in other regions and periods to determine whether the methodologies explored in this investigation can be applied elsewhere and whether the patterns highlighted in this investigation extend beyond this period and region. Several sites potentially suitable for such assessment have been identified throughout the course of this research (Table 11.1). Each of these sites fulfils the criteria for the selection of sites for micro-level analysis (see Section 5.1.3), including published site plans and detailed description of archaeological features.

Table 11.1. A sample of recommended sites for extension of this research beyond the PPN central and southern Levant.

Site	Period	Details	Previous population estimate	Reference
Khirokitia, Cyprus	Cypro-PPNB (c. 7,000 BC)	Curvilinear stone structures; possible two-storey; courtyards and roofed corridors; egalitarian society	300-600 5000	Mellaart 1967; Le Brun 1994 Aurenche 1981
Çatalhöyük (East Mound), Turkey	Aceramic Neolithic (c. 7,000 BC)	Rectilinear, agglomerated stone structures; roof access; sleeping platforms; agro-pastoralists	3500-8000	Düring 2013, p.35
Banpo, Xi'an, China	Neolithic (c. 4,000 BC)	Semi-subterranean, curvilinear and rectilinear, organic structures; agro-pastoralists; pottery	500-600	Perkins 2013, p.597
Skara Brae, Orkney Islands, UK	Neolithic (c. 3,000 BC)	Square and curvilinear stone structures; connected by roofed passageways; sleeping compartments; agro-pastoralists	50-80	Ginenthal 2015, p. 371; Clarke and Maguire 2000
Castle Rock Pueblo, Colorado, USA	Prehistoric (c. AD 1,250)	Rectilinear stone structures; agro-pastoralists; pottery	75-150	Kuckelman 2000

7. Research into evidence for rival authoritative figures and political stratification:

Alder (1990) hypothesised a minimum group size threshold of 1,500 people for the development of politically stratified communities. Population estimates for several villages produced in this investigation exceed this threshold (i.e. LPPNB 'Ain Jamam and Tell 'Ain el-Kerkh/Tell el-Kerkh II; LPPNB/PPNC 'Ain Ghazal and Basta; and PPNC Beisamoun). These could provide suitable case studies for exploring potential evidence for rival authority figures and political stratification during the PPN.

8. Group size thresholds and cultural evolution:

The group size thresholds proposed in this investigation present several avenues for further investigation into the relationship between demographic parameters and social, technological, economic, cultural and, potentially, political developments during the NDT. In particular, further research into changing subsistence strategies could explore the relationship between scaled population sizes and population pressure on resources or the capacity for cooperative and/or experimental human behaviour that may have led to innovative developments in food procurement strategies (i.e. the minimum population size required for specific tasks). Research relating to the introduction of mechanisms for reducing scalar stress and promoting social cohesion could explore the relationship between group size and household economic independence, architectural innovations and ritual practices. Research into emerging social complexity could explore the relationship between population size and craft specialisation, major technological developments, social and labour differentiation, and the rise of authoritative individuals.

An additional avenue for further research could involve re-examination of group size thresholds based on aggregate populations of settlements clusters. In this investigation, it appears that many developments may have occurred at lower population sizes than previously suggested. This could indicate that groups of interacting settlements may have acted as a larger regional population.

11.2 Concluding statement

The methodology for producing population estimates of PPN villages in the central and southern Levant has been completely revised in this investigation. This research presents the largest site-specific assessment of population parameters for PPN villages to date, including detailed micro-level assessment of 15 sites, and the reconstruction of individual estimates of population size, people per dwelling, residential floor area per person and people per hectare for an additional 91 sites. An assessment of the pre-existing population estimates and the underlying methodologies has suggested that these may not be suitable even for comparative analysis. Current theories reliant on these pre-existing estimates should be reviewed in light of the more empirically and statistically robust population estimates produced in this investigation.

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Appendix A: Data used to construct storage provisions formulae

Data from Hemsley (2008): data highlighted in grey utilised to create formulae

Site	Structure	Estimated floor area (m^2)	Maximum number of 1.65 m and 1.83 m tall sleeping occupants per structure based on amount of storage					
			None		*0.46 m^3 per person*		*2 x 0.46 m^3 per person*	
			Range	*Mid-point*	*Range*	*Mid-point*	*Range*	*Mid-point*
Jericho (PPNA) (p.141)	E5 (xvib)	10.88	2-5	3.5	2	2	2	2
	E5 & E6	11.74	3-8	5.5	2-3	2.5	2	2
	E5 (x)	8.50	2-4	3	2	2	2	2
	MH (xxxvii)	9.20	3-5	4	2	2	2	2
	MH & MJ	30.60	8-17	12.5	6-7	6.5	4-5	4.5
	MJ (xliii)	20.00	4-6	5	4-5	4.5	2-3	2.5
Netiv Hagdud (PPNA) (p.180)	L50	6.07	1	1			1	1
	L26	6.9	2-3	2.5			2	2
	L37	7.55	2-3	2.5			2	2
	L08x	8.4	2-3	2.5			2	2
	L55	9.76	2-4	3			2	2
	L57	10.38	3-5	4			2	2
	L22	16.28	5-9	7			3	3
	L08y	16.8	3-8	5.5			3	3
	L21	25.96	7-13	10			6	6
	L40	36.61	9-19	14			7	7
	L08x/y total	24.48	5-11	8			4-5	4.5
Jericho (MPPNB) (p.243)	Trench I Stage XVI: A	21.7	6-11	8.5	5-8	6.5	6-11	8.5
	Trench M Stage XV: A	17.5	5-8	6.5	5-8	6.5	5-8	6.5
Basta (LPPNB) (p.288)	10/16	22.40	7-13	10				
	19/20	8.19	2-5	3.5				
	27b	6.27	1-3	2				
	17	4.45	1-2	1.5				
	18	2.97	0-2	1				

Appendix B.1: Beidha site data and micro-level estimates

Subphase A1

Assessable area (m²)	Assessable area	132.17
	Unassessable area	-
	Total	**132.17**
Potential residential built area (m²)	Building 18*	17.76
	Building 41	12.77
	Building 48*	23.51
	Building 49	20.81
	Total	**74.85**
	Mean	18.71
	SD (±)	4.61
	*Mean residential built area: complete dwellings	20.64
Potential non-residential built area (m²)	Building 17	5.82
	Building 50	6.10
	Total	**11.92**

Built area (m²)	Potential residential built area	74.85
	Potential non-residential built area	11.92
	Total	**86.77**
Potential residential floor area (m²)	Building 18*	9.23
	Building 41	6.50
	Building 48*	13.88
	Building 49	9.23
	Total	**38.84**
	*Mean residential floor area: complete dwellings	11.56
Built floor area (m²)	Building 17	3.08
	Building 18*	9.23
	Building 41	6.50
	Building 48*	13.88
	Building 49	9.23
	Building 50*	3.31
	Total	**45.23**

Subphase A2

Assessable area (m²)	Assessable area	298.22
	Baulk	4.69
	Unassessable area	-
	Total	**293.53**
Potential residential built area (m²)	Building 33*	12.53
	Building 38	17.66
	Building 51	9.87
	Building 53	13.44
	Building 54*	17.17
	Building 55	7.63
	Building 56	12.31
	Building 74*	14.72
	Building 83	11.47
	Total	**116.81**
	Mean	12.98
	SD (±)	3.24
	*Mean residential built area: complete dwellings	14.81
Potential non-residential built area (m²)	Building 21	8.85
	Building 37	30.60
	Buildings 29	4.07
	Buildings 52	1.78
	Building ?(a)	2.46
	Building ?(b)	3.37
	Total	**51.13**
Built area (m²)	Potential residential built area	116.81
	Potential non-residential built area	51.13
	Total	**167.94**

Potential residential floor area (m²)	Building 33*	3.68
	Building 38	10.31
	Building 51	4.98
	Building 53	7.02
	Building 54*	10.03
	Building 55	4.82
	Building 56	4.45
	Building 74*	8.07
	Building 83	4.77
	Total	**58.13**
	*Mean residential floor area: complete dwellings	7.26
Built floor area (m²)	Building 21	4.34
	Building 29	1.29
	Building 33	3.68
	Building 37	18.17
	Building 38	10.31
	Building 51	4.98
	Building 52	0.89
	Building 53	7.02
	Building 54	10.03
	Building 55	4.82
	Building 56	4.45
	Building 74	8.07
	Building 83	4.77
	Building ?(a)	1.40
	Building ?(b)	3.15
	Total	**87.37**

Storage provisions formula (SPF)

			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	297.07	0.3944 x 297.07	=	117.16	0.2477 x 297.07	=	73.58	0.1903 x 297.07	=	56.53
P	=	?	117.16 - 0.375	=	116.79	73.58 + 0.0339	=	73.62	56.53 + 0.3976	=	56.93
			P	**=**	**116.79**	**P**	**=**	**73.62**	**P**	**=**	**56.93**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	7.26	0.3944 x 7.26	=	2.86	0.2477 x 7.26	=	1.80	0.1903 x 7.26	=	1.38
P	=	?	2.86 - 0.375	=	2.49	1.8 + 0.0339	=	1.83	1.38 + 0.3976	=	1.74
			P	**=**	**2.49**	**P**	**=**	**1.83**	**P**	**=**	**1.74**
						Total number of contemporaneous dwellings					*45.99*
		Total population			**114.44**			**84.27**			**80.07**
Mean total population					**115.62**			**78.94**			**68.50**

Naroll's (1962) AGF1

Data required		
SPF population estimate (P) based on amount of storage:	None	115.62
	Moderate	78.94
	Maximum	68.50
Residential floor area as a proportion of built floor area (%)		66.54
Total built floor area (m^2) (A)		*595.31*
Built floor area in assessable area (m^2)		*87.37*
Proportion of site assessable (%)		*14.68*
Total residential floor area (m^2) (RADC method)		*396.09*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	5.15
	Moderate	7.54
	Maximum	8.69
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.57
	Moderate	3.76
	Maximum	4.34
Total contemporaneous residential floor area (m^2) (RADC method)		297.07

$A = a \times P^b$

Amount of storage:

None

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC

A	=	?	**$A = 21.7 \times 115.62^{0.84195}$**		
P	=	115.62	$115.62^{0.84195}$	=	54.57
a	=	21.7	21.7 x 54.57	=	1184.18
b	=	0.84195	**A**	**=**	**1184.18**
Built floor area per person (m^2)					**10.24**
RADC (m^2 per person)					**6.81**
Residential floor area as a proportion of built floor area					*66.54*

Method 2: Re-calculated initial growth index (*a*)

A	=	595.31	**$595.31 = a \times 115.62^{0.84195}$**		
P	=	115.62	$115.62^{0.84195}$	=	54.57
a	=	?	595.31/54.57	=	10.91
b	=	0.84195	***A***	**=**	**10.91**

Moderate

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC

A	=	?	**$A = 21.7 \times 78.94^{0.84195}$**		
P	=	78.94	$78.94^{0.84195}$	=	39.58
a	=	21.7	21.7 x 39.58	=	858.81
b	=	0.84195	**A**	**=**	**858.81**
Built floor area per person (m^2)					**10.88**
RADC (m^2 per person)					**7.24**
Residential floor area as a proportion of built floor area					*66.54*

Method 2: Re-calculated initial growth index (*a*)

A	=	595.31	**$595.31 = a \times 78.94^{0.84195}$**		
P	=	78.94	$78.94^{0.84195}$	=	39.58
a	=	?	595.31/39.58	=	15.04
b	=	0.84195	***a***	**=**	**15.04**

Maximum

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC

A	=	?	**$A = 21.7 \times 68.5^{0.84195}$**		
P	=	68.50	$68.5^{0.84195}$	=	35.12
a	=	21.7	21.7 x 35.12	=	762.09
b	=	0.84195	**A**	**=**	**762.09**
Built floor area per person (m^2)					**11.13**
RADC (m^2 per person)					**7.40**
Residential floor area as a proportion of built floor area					*66.54*

Method 2: Re-calculated initial growth index (*a*)

A	=	595.31	**$595.31 = a \times 68.5^{0.84195}$**		
P	=	68.50	$68.5^{0.84195}$	=	35.12
a	=	?	595.31/35.12	=	16.95
b	=	0.84195	***a***	**=**	**16.95**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		2000
SPF population estimate (P) based on amount of storage:	None	115.62
	Moderate	78.94
	Maximum	68.50

Amount of storage:		$A = a \times P^b$					
	None	**Open settlements**			**$2000 = a \times 115.62^2$**		
		A	=	2000			
		P	=	115.62	115.62^2	=	13367.12
		a	=	?	2000/13367.12	=	0.15
		b	=	2	***a***	**=**	**0.15**
		Village settlements			**$2000 = a \times 115.62^1$**		
		A	=	2000			
		P	=	115.62	115.62^1	=	115.62
		a	=	?	2000/115.62	=	17.3
		b	=	1	***a***	**=**	**17.30**
		Urban settlements			**$2000 = a \times 115.62^{0.6667}$**		
		A	=	2000			
		P	=	115.62	$115.62^{0.6667}$	=	23.74
		a	=	?	2000/23.74	=	84.26
		b	=	0.6667	***a***	**=**	**84.26**
	Moderate	**Open settlements**			**$2000 = a \times 78.94^2$**		
		A	=	2000			
		P	=	78.94	78.94^2	=	6231.86
		a	=	?	2000/6231.86	=	0.32
		b	=	2	***a***	**=**	**0.32**
		Village settlements			**$2000 = a \times 78.94^1$**		
		A	=	2000			
		P	=	78.94	78.94^1	=	78.94
		a	=	?	2000/78.94	=	25.3
		b	=	1	***a***	**=**	**25.34**
		Urban settlements			**$2000 = a \times 78.94^{0.6667}$**		
		A	=	2000			
		P	=	78.94	$78.94^{0.6667}$	=	18.40
		a	=	?	2000/18.4	=	108.67
		b	=	0.6667	***a***	**=**	**108.67**
	Maximum	**Open settlements**			**$2000 = a \times 68.5^2$**		
		A	=	2000			
		P	=	68.50	68.5^2	=	4691.98
		a	=	?	2000/4691.98	=	0.43
		b	=	2	***a***	**=**	**0.43**
		Village settlements			**$2000 = a \times 68.5^1$**		
		A	=	2000			
		P	=	68.50	68.5^1	=	68.50
		a	=	?	2000/68.5	=	29.2
		b	=	1	***a***	**=**	**29.20**
		Urban settlements			**$2000 = a \times 68.5^{0.6667}$**		
		A	=	2000			
		P	=	68.50	$68.5^{0.6667}$	=	16.74
		a	=	?	2000/16.74	=	119.45
		b	=	0.6667	***a***	**=**	**119.45**

Subphase B2

Assessable area (m^2)	Assessable area	610.86
	Baulks	10.94
	Unassessable area	-
	Total	**599.92**
Potential residential built area (m^2)	Building 25*	11.97
	Building 34	10.92
	Building 36*	14.71
	Building 44	4.01
	Building 47*	10.47
	Building 60*	12.72
	Building 61	14.25
	Building 82	11.77
	Total	**90.82**
	Mean	11.35
	SD (±)	3.32
	*Mean residential built area: complete dwellings	12.47
Potential non-residential built area (m^2)	Building 15	2.73
	Building 26	31.41
	Building 31	19.98
	Building 32	6.73
	Building 43	5.17
	Building 81	14.14
	Total	**80.16**
Built area (m^2)	Potential residential built area	90.82
	Potential non-residential built area	80.16
	Total	**170.98**

Potential residential floor area (m^2)	Building 25*	7.69
	Building 34*	5.84
	Building 36*	6.74
	Building 44	2.25
	Building 47*	6.29
	Building 60*	6.02
	Building 61	9.17
	Building 82	5.82
	Total	**49.82**
	*Mean residential floor area: complete dwellings	6.52
Built floor area (m^2)	Building 15	1.06
	Building 25	7.69
	Building 26	26.06
	Building 31	11.96
	Building 32	3.84
	Building 34	5.84
	Building 36	6.74
	Building 43	1.37
	Building 44	2.25
	Building 47	6.29
	Building 60	6.02
	Building 61	9.17
	Building 81	8.18
	Building 82	5.82
	Total	**102.29**

Storage provisions formula (SPF)

			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	282.91	0.3944 x 282.91	=	111.58	0.2477 x 282.91	=	70.08	0.1903 x 282.91	=	53.84
P	=	?	111.58 - 0.375	=	111.20	70.08 + 0.0339	=	70.11	53.84 + 0.3976	=	54.23
			P	**=**	**111.20**	**P**	**=**	**70.11**	**P**	**=**	**54.23**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	6.52	0.3944 x 6.52	=	2.57	0.2477 x 6.52	=	1.62	0.1903 x 6.52	=	1.24
P	=	?	2.57 - 0.375	=	2.20	1.62 + 0.0339	=	1.65	1.24 + 0.3976	=	1.60
			P	**=**	**2.20**	**P**	**=**	**1.65**	**P**	**=**	**1.60**
						Total number of contemporaneous dwellings					*50.07*
		Total population			**109.98**			**82.57**			**80.12**
Mean total population					**110.59**			**76.34**			**67.18**

Naroll's (1962) AGF1

Data required		
SPF population estimate (P) based on amount of storage:	None	110.59
	Moderate	76.34
	Maximum	67.18
Residential floor area as a proportion of built floor area (%)		66.52
Total built floor area (m^2) (A)		*595.40*
Subphase B2 built floor area in assessable area (%)		*29.77*
Total site extent (m^2)		*2000*
Total residential floor area (m^2) (RADC method)		*396.06*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	5.38
	Moderate	7.80
	Maximum	8.86
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.56
	Moderate	3.71
	Maximum	4.21
Total contemporaneous residential floor area (m^2) (RADC method)		*282.91*

$A = a \times P^b$

Amount of storage:							
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 110.59^{0.84195}$**			
	P	=	110.59	$110.59^{0.84195}$		=	52.57
	a	=	21.7	21.7 x 52.57		=	1140.72
	b	=	0.84195	**A**		**=**	**1140.72**
	Built floor area per person (m^2)						**10.31**
	RADC (m^2 per person)						**6.86**
				Residential floor area as a proportion of built floor area			*66.52*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	595.40	**595.40 = *a* x $110.59^{0.84195}$**			
	P	=	110.59	$110.59^{0.84195}$		=	52.57
	a	=	?	595.40/52.57		=	11.33
	b	=	0.84195	***A***		**=**	**11.33**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 76.34^{0.84195}$**			
	P	=	76.34	$76.34^{0.84195}$		=	38.47
	a	=	21.7	21.7 x 38.47		=	834.89
	b	=	0.84195	**A**		**=**	**834.89**
	Built floor area per person (m^2)						**10.94**
	RADC (m^2 per person)						**7.28**
				Residential floor area as a proportion of built floor area			*66.52*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	595.40	**595.40 = *a* x $76.34^{0.84195}$**			
	P	=	76.34	$76.34^{0.84195}$		=	38.47
	a	=	?	595.40/38.47		=	15.48
	b	=	0.84195	***a***		**=**	**15.48**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 67.18^{0.84195}$**			
	P	=	67.18	$67.18^{0.84195}$		=	34.55
	a	=	21.7	21.7 x 34.55		=	749.70
	b	=	0.84195	**A**		**=**	**749.70**
	Built floor area per person (m^2)						**11.16**
	RADC (m^2 per person)						**7.42**
				Residential floor area as a proportion of built floor area			*66.52*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	595.40	**595.40 = *a* x $67.18^{0.84195}$**			
	P	=	67.18	$67.18^{0.84195}$		=	34.55
	a	=	?	595.40/34.55		=	17.23
	b	=	0.84195	***a***		**=**	**17.23**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		2000
SPF population estimate (P) based on amount of storage:	None	110.59
	Moderate	76.34
	Maximum	67.18

Amount of storage:					$A = a \times P^b$		
None	**Open settlements**				**$2000 = a \times 110.59^2$**		
	A	=	2000				
	P	=	110.59	110.59^2		=	12231.01
	a	=	?	2000/12231.01		=	0.16
	b	=	2	***a***		**=**	**0.16**
	Village settlements				**$2000 = a \times 110.59^1$**		
	A	=	2000				
	P	=	110.59	110.59^1		=	110.59
	a	=	?	2000/110.59		=	18.1
	b	=	1	***a***		**=**	**18.08**
	Urban settlements				**$2000 = a \times 110.59^{0.6667}$**		
	A	=	2000				
	P	=	110.59	$110.59^{0.6667}$		=	23.04
	a	=	?	2000/23.04		=	86.79
	b	=	0.6667	***a***		**=**	**86.79**
Moderate	**Open settlements**				**$2000 = a \times 76.34^2$**		
	A	=	2000				
	P	=	76.34	76.34^2		=	5827.43
	a	=	?	2000/5827.43		=	0.34
	b	=	2	***a***		**=**	**0.34**
	Village settlements				**$2000 = a \times 76.34^1$**		
	A	=	2000				
	P	=	76.34	76.34^1		=	76.34
	a	=	?	2000/76.34		=	26.2
	b	=	1	***a***		**=**	**26.20**
	Urban settlements				**$2000 = a \times 76.34^{0.6667}$**		
	A	=	2000				
	P	=	76.34	$76.34^{0.6667}$		=	18.00
	a	=	?	2000/18.00		=	111.12
	b	=	0.6667	***a***		**=**	**111.12**
Maximum	**Open settlements**				**$2000 = a \times 67.18^2$**		
	A	=	2000				
	P	=	67.18	67.18^2		=	4512.76
	a	=	?	2000/4512.76		=	0.44
	b	=	2	***a***		**=**	**0.44**
	Village settlements				**$2000 = a \times 67.18^1$**		
	A	=	2000				
	P	=	67.18	67.18^1		=	67.18
	a	=	?	2000/67.18		=	29.8
	b	=	1	***a***		**=**	**29.77**
	Urban settlements				**$2000 = a \times 67.18^{0.6667}$**		
	A	=	2000				
	P	=	67.18	$67.18^{0.6667}$		=	16.53
	a	=	?	2000/16.53		=	121.01
	b	=	0.6667	***a***		**=**	**121.01**

Subphase C2

Assessable area (m^2)		Assessable area			962.61
		Baulks			5.94
		Unassessable area			-
		Total			**957.64**
Potential residential built area (m^2)	Upper storey	Building 1	13.08	Building 14*	21.54
		Building 2(*)	39.91	Building 19*	33.17
		Building 3*	32.75	Building 71	8.63
		Building 4*	29.11	Building 72	15.90
		Building 5*	23.57	Building 73	21.64
		Building 10*	29.92	Building W of 14	10.07
		Building 12*	25.17	Building W of 19	7.57
		Building 13(*)	30.62		
		Total			**342.65**
		Mean			22.84
		SD (±)			9.99
		*Mean residential built area: complete dwellings ((*) marginally incomplete building)			29.53
Potential non-residential built area (m^2)	Ground floor	Building 1	13.08	Building 13	30.62
		Building 2	39.91	Building 14	21.54
		Building 3	32.75	Building 19	33.17
		Building 4	29.11	Building 71	8.63
		Building 5	23.57	Building 72	15.90
		Building 8	155.35	Building 73	21.64
		Building 10	29.92	Structures 75/76	54.38
		Building 11	15.97	Building W of 14	10.07
		Building 12	25.17	Building W of 19	7.57
		Total			**568.35**
Built area (m^2)		Potential residential built area (ground floor)			-
		Potential non-residential built area			568.35
		Total			**568.35**

				Adjusted			Adjusted
Potential residential floor area (m^2)	Upper storey	Building 1	10.62	8.76	Building 14*	15.23	13.48
		Building 2*	30.81	25.42	Building 19*	25.95	21.41
		Building 3*	21.79	18.39	Building 71	6.32	5.21
		Building 4*	13.14	10.84	Building 72	12.86	10.61
		Building 5*	16.95	13.98	Building 73(*)	13.10	12.02
		Building 10*	23.02	18.99	Building W of 14	7.17	5.91
		Building 12*	19.43	16.03	Building W of 19	5.35	4.42
		Building 13*	25.43	20.98			
	Total					**247.16**	**206.45**
	*Mean residential floor area: complete dwellings					21.31	17.15
Built floor area (m^2)	Ground floor	Building 1	6.43		Building 13	13.43	
		Building 2	15.63		Building 14	9.98	
		Building 3	15.51		Building 19	12.23	
		Building 4	4.44		Building 71	3.21	
		Building 5	8.60		Building 72	7.70	
		Building 8	95.69		Building 73	8.36	
		Building 10	10.89		Structures 75/76	35.94	
		Building 11	4.18		Building W of 14	3.32	
		Building 12	10.86		Building W of 19	2.81	
	Upper storey	Building 1	10.62	8.76	Building 14	15.23	13.48
		Building 2	30.81	25.42	Building 19	25.95	21.41
		Building 3	21.79	18.39	Building 71	6.32	5.21
		Building 4	19.77	10.84	Building 72	12.86	10.61
		Building 5	16.95	13.98	Building 73	13.10	12.02
		Building 10	23.02	18.99	Building W of 14	7.17	5.91
		Building 12	19.43	16.03	Building W of 19	5.35	4.42
		Building 13	25.43	20.98			
	Total					**523.00**	**475.66**

Storage provisions formula (SPF)

			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	503.04	0.3944 x 503.04	=	198.40	0.2477 x 503.04	=	124.60	0.1903 x 503.04	=	95.73
P	=	?	198.40 - 0.375	=	198.02	124.60 + 0.0339	=	124.64	95.73 + 0.3976	=	96.13
			P	**=**	**198.02**	**P**	**=**	**124.64**	**P**	**=**	**96.13**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	17.15	0.3944 x 17.15	=	6.76	0.2477 x 17.15	=	4.25	0.1903 x 17.15	=	3.26
P	=	?	6.76 - 0.375	=	6.39	4.25 + 0.0339	=	4.28	3.26 + 0.3976	=	3.62
			P	**=**	**6.39**	**P**	**=**	**4.28**	**P**	**=**	**3.62**
						Total number of contemporaneous dwellings					*36.55*
		Total population			**233.51**			**156.50**			**132.42**
Mean total population					**215.77**			**140.57**			**114.27**

Naroll's (1962) AGF1

Data required

SPF population estimate (P) based on amount of storage:	None	215.77
	Moderate	140.57
	Maximum	114.27
Residential floor area as a proportion of built floor area (%)		43.40
Total built floor area (m^2) (A)		*1490.10*
Built floor area in assessable area (m^2)		*475.66*
Proportion of site assessable (%)		*31.92*
Total residential floor area (m^2) (RADC method)		*646.75*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	6.91
	Moderate	10.60
	Maximum	13.04
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.33
	Moderate	3.58
	Maximum	4.40
Total contemporaneous residential floor area (m^2) (RADC method)		503.04

$A = a \times P^b$

Amount of storage:

None

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC					
A	=	?	**$A = 21.7 \times 215.77^{0.84195}$**		
P	=	215.77	$215.77^{0.84195}$	=	92.28
a	=	21.7	21.7 x 92.28	=	2002.44
b	=	0.84195	**A**	**=**	**2002.44**
Built floor area per person (m^2)					**9.28**
RADC (m^2 per person)					**4.03**
			Residential floor area as a proportion of built floor area		*43.40*
Method 2: Re-calculated initial growth index (*a*)					
A	=	1490.10	**$1490.10 = a \times 215.77^{0.84195}$**		
P	=	215.77	$215.77^{0.84195}$	=	92.28
a	=	?	1490.10/92.28	=	16.15
b	=	0.84195	***a***	**=**	**16.15**

Moderate

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC					
A	=	?	**$A = 21.7 \times 140.57^{0.84195}$**		
P	=	140.57	$140.57^{0.84195}$	=	64.33
a	=	21.7	21.7 x 64.33	=	1395.97
b	=	0.84195	**A**	**=**	**1395.97**
Built floor area per person (m^2)					**9.93**
RADC (m^2 per person)					**4.31**
			Residential floor area as a proportion of built floor area		*43.40*
Method 2: Re-calculated initial growth index (*a*)					
A	=	1490.10	**$1490.10 = a \times 140.57^{0.84195}$**		
P	=	140.57	$140.57^{0.84195}$	=	64.33
a	=	?	1490.10/64.33	=	23.16
b	=	0.84195	***a***	**=**	**23.16**

Maximum

Method 1: Total built floor area (m^2) (A), built floor area per person and RADC					
A	=	?	**$A = 21.7 \times 114.27^{0.84195}$**		
P	=	114.27	$114.27^{0.84195}$	=	54.04
a	=	21.7	21.7 x 54.04	=	1172.57
b	=	0.84195	**A**	**=**	**1172.57**
Built floor area per person (m^2)					**10.26**
RADC (m^2 per person)					**4.45**
			Residential floor area as a proportion of built floor area		*43.40*
Method 2: Re-calculated initial growth index (*a*)					
A	=	1490.10	**$1490.10 = a \times 114.27^{0.84195}$**		
P	=	114.27	$114.27^{0.84195}$	=	54.04
a	=	?	1490.10/54.04	=	27.58
b	=	0.84195	***a***	**=**	**27.58**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		3000
SPF population estimate (P) based on amount of storage:	None	215.77
	Moderate	140.57
	Maximum	114.27

A = *a* x P^b

Amount of storage:							
None	**Open settlements**			**3000 = *a* x 215.77^2**		
	A	=	3000			
	P	=	215.77	215.77^2	=	46555.65
	a	=	?	3000/46555.65	=	0.06
	b	=	2	***a***	**=**	**0.06**
	Village settlements			**3000 = *a* x 215.77^1**		
	A	=	3000			
	P	=	215.77	215.77^1	=	215.77
	a	=	?	3000/215.77	=	13.9
	b	=	1	***a***	**=**	**13.90**
	Urban settlements			**3000 = *a* x $215.77^{0.6667}$**		
	A	=	3000			
	P	=	215.77	$215.77^{0.6667}$	=	35.98
	a	=	?	3000/35.98	=	83.38
	b	=	0.6667	***a***	**=**	**83.38**
Moderate	**Open settlements**			**3000 = *a* x 140.57^2**		
	A	=	3000			
	P	=	140.57	140.57^2	=	19759.76
	a	=	?	3000/19759.76	=	0.15
	b	=	2	***a***	**=**	**0.15**
	Village settlements			**3000 = *a* x 140.57^1**		
	A	=	3000			
	P	=	140.57	140.57^1	=	140.57
	a	=	?	3000/140.57	=	21.3
	b	=	1	***a***	**=**	**21.34**
	Urban settlements			**3000 = *a* x $140.57^{0.6667}$**		
	A	=	3000			
	P	=	140.57	$140.57^{0.6667}$	=	27.04
	a	=	?	3000/27.04	=	110.95
	b	=	0.6667	***a***	**=**	**110.95**
Maximum	**Open settlements**			**3000 = *a* x 114.27^2**		
	A	=	3000			
	P	=	114.27	114.27^2	=	13057.84
	a	=	?	3000/13057.84	=	0.23
	b	=	2	***a***	**=**	**0.23**
	Village settlements			**3000 = *a* x 114.27^1**		
	A	=	3000			
	P	=	114.27	114.27^1	=	114.27
	a	=	?	3000/114.27	=	26.3
	b	=	1	***a***	**=**	**26.25**
	Urban settlements			**3000 = *a* x $114.27^{0.6667}$**		
	A	=	3000			
	P	=	114.27	$114.27^{0.6667}$	=	23.55
	a	=	?	3000/23.55	=	127.38
	b	=	0.6667	***a***	**=**	**127.38**

Appendix B.2: Beidha micro-level estimate database

		Site	Beidha (A1)	Beidha (A2)	Beidha (B2)	Beidha (C2)
Site Information		Settlement type	1	1	1	3
		Period	MPPNB	MPPNB	MPPNB	LPPNB
		Site extent (hectares)	0.1	0.2	0.2	0.3
		Site extent (hectares) used in calculations of population size	-	-	-	-
		Site extent category (hectares)	<0.4	<0.4	<0.4	≤0.5
		Structural contemporaneity value (%)	71.43	75	71.43	77.78
		Environment	Restricted	Restricted	Restricted	Restricted
		Subsistence (H-Hunt; G-Gath; C-Cult; P-Past)	H, G	H, G	H, G, C	H, G, C, P
		Dwelling architecture: predominant shape	Curvilinear	Curvilinear	Curvilinear	Rectilinear
		Dwelling architecture: predominant number of storeys	Single	Single	Single	Multiple
		Dwelling architecture: degree of compartmentalisation	Limited	Limited	Limited	High
		Economy: household economic independence	Limited-Mod	Limited-Mod	Limited-Mod	Moderate
		Ritual	Established	Established	Established	Established
		Complexity in community organisation	Limited	Limited	Evident	Evident
Housing Unit Method	Data	Dwelling count	4	9	8	15
		Assessable area (m^2)	132.17	293.53	599.92	957.64
		Proportion of site assessable (%)	13.22	14.68	30	31.92
		Total number of dwellings	30.26	61.32	70.1	46.99
		Mean residential built area (m^2)	18.71	12.98	11.35	22.84
		Assessable built area (m^2)	86.77	167.94	170.98	568.35
		Proportion of built area in assessable area (%)	65.65	57.21	28.5*	59.35
		Total built area (m^2)	656.5	1144.28	1144.18	1780.47
		Assessable residential built area (m^2)	74.85	116.81	90.82	342.65
		Proportion of residential built area in built area (%)	86.26	69.55	53.12*	60.29
		Total residential built area (m^2)	566.32	795.89	795.82	1073.42
		Proportion of residential built area in assessable area (%)	56.63	39.79	15.14*	35.78
	Estimates	Total number of contemporaneous dwellings	21.62	45.99	50.07	36.55
		Total population (3 people)	64.85	137.98	150.22	109.65
		Total population (5.5 people)	118.9	252.96	275.4	201.02
		Total population (8 people)	172.94	367.94	400.58	292.39
		Suitable family sizes	All	3 people	3 people	All

			Site		Beidha (A1)	Beidha (A2)	Beidha (B2)	Beidha (C2)
Residential Area Density Coefficient Method	Data		Assessable residential floor area (m^2)		38.84	58.13	49.82	206.45
			Total residential floor area (m^2)		293.88	396.09	396.06	646.75
			Proportion of residential floor area in built area (%)		44.76	34.61	29.14*	36.32
			Proportion of residential floor area in assessable area (%)		29.39	19.8	8.3*	21.56
	Estimates		Total contemporaneous residential floor area (m^2)		209.92	297.07	282.91	503.04
			Total population (1.77 m^2 per person)		118.6	167.84	159.83	284.2
			Total population (3.3 m^2 per person)		63.61	90.02	85.73	152.44
			Total population (5 m^2 per person)		41.98	59.41	56.58	100.61
			Suitable RADCs		All	All	All	All
Storage Provisions Formulae	Data		Total contemporaneous residential floor area (m^2)		209.92	297.07	282.91	503.04
			Mean residential floor area of complete dwellings (m^2)		11.56	7.26	6.52	17.15
			Total number of contemporaneous dwellings		21.62	45.99	50.07	36.55
			Probable amount of interior residential storage		None-moderate	None-moderate	None-moderate	None-moderate
	Estimates	Total population (SPF1 and 2)	No storage (min)		82.42	114.44	109.98	198.02
			No storage (max)		90.45	116.79	111.2	233.51
			0.46^3 storage per person (min)		52.03	73.62	70.11	124.64
			0.46^3 storage per person (max)		62.63	84.27	82.57	156.5
			2 x 0.46^3 storage per person (min)		40.35	56.93	54.23	96.13
			2 x 0.46^3 storage per person (max)		55.32	80.07	80.12	132.42
		People per dwelling (SPF2)	No storage		4.18	2.49	2.2	6.39
			0.46^3 storage per person		2.9	1.83	1.65	4.28
			2 x 0.46^3 storage per person		2.56	1.74	1.6	3.62
Allometric Growth Formulae	Data		Total built floor area (m^2)		342.21	595.31	595.4	1490.1
			Proportion of residential floor area in built floor area (%)		85.88	66.54	66.52	43.4
	Naroll (AGF1)		Total built floor area (m^2)	No storage	926.96	1140.72	1140.72	2002.44
				Mod storage	656.06	834.89	834.89	1395.97
				Max storage	563.27	749.7	749.7	1172.57
			Built floor area per person (m^2)	No storage	10.72	10.31	10.31	9.28
				Mod storage	11.44	10.94	10.94	9.93
				Max storage	11.78	11.16	11.16	10.26
			RADC (m^2 residential floor area per person)	No storage	9.21	6.86	6.86	4.03
				Mod storage	9.83	7.28	7.28	4.31
				Max storage	10.11	7.42	7.42	4.45
			Re-calculated initial growth index	No storage	8.01	11.33	11.33	16.15
				Mod storage	11.32	15.48	15.48	23.16
				Max storage	13.18	17.23	17.23	27.58

		Site		Beidha (A1)	Beidha (A2)	Beidha (B2)	Beidha (C2)
Allometric Growth Formulae	Wiessner (AGF2 initial growth indices)	Predominant settlement type/s		Open/village	Open/village	Open/village	Village/urban
		Open	No storage	0.13	0.15	0.16	0.06
			Mod storage	0.3	0.32	0.34	0.15
			Max storage	0.44	0.43	0.44	0.23
		Village	No storage	11.57	17.3	18.08	13.9
			Mod storage	17.44	25.34	26.2	21.34
			Max storage	20.91	29.2	29.77	26.25
		Urban	No storage	51.15	84.26	86.79	83.38
			Mod storage	67.25	108.67	111.12	110.95
			Max storage	75.88	119.45	121.01	127.38
Settlement Population Density Coefficient Method	Total population based on:	90 people/ha		9	18	18	27
		150 people/ha		15	30	30	45
		294 people/ha		29.4	58.8	58.8	88.2
	Population in assessable area:	90 people/ha		1.19	2.64	5.4	8.62
		150 people/ha		1.98	4.4	9	14.36
		294 people/ha		3.89	8.63	17.64	28.15
	Contemporaneous dwellings in assessable area			2.86	6.75	15.02	11.67
	People per dwelling in assessable area:	90 people/ha		0.42	0.39	0.36	0.74
		150 people/ha		0.69	0.65	0.6	1.23
		294 people/ha		1.36	1.28	1.17	2.41

		Site	Beidha (A1)	Beidha (A2)	Beidha (B2)	Beidha (C2)
Final Estimates	Total population	HUM	64.85-172.94	137.98	150.22	109.65-292.39
		RADC	41.98-118.6	59.41-167.84	56.58-159.83	100.61-284.2
		SPF	57.33-86.44	78.94-115.62	76.34-110.59	140.57-215.77
		SPDC	9-29.4	18-58.8	18-58.8	27-88.2
	People per dwelling	HUM	3-8	3	3	3-8
		RADC	1.94-5.49	1.29-3.65	1.13-3.19	2.75-7.78
		SPF1	2.65-4	1.72-2.51	1.52-2.21	3.85-5.9
		SPF2	2.9-4.18	1.83-2.49	1.65-2.2	4.28-6.39
		SPDC	0.42-1.36	0.39-1.28	0.36-1.17	0.74-2.41
	Residential floor area density coefficient	HUM	1.21-3.24	2.15	2.15	1.72-4.59
		RADC	1.77-5	1.77-5	1.77-5	1.77-5
	(m^2 per person)	SPF	2.43-3.66	2.57-3.76	2.56-3.71	2.33-3.58
		AGF1	9.21-9.83	6.81-7.24	6.86-7.28	4.03-4.31
		SPDC	7.14-23.32	5.05-16.5	4.81-15.72	5.7-18.63
	Settlement population density coefficient	HUM	648.53-1729.41	689.9	751.1	365.49-974.65
		RADC	419.84-1185.99	297.05-839.18	282.91-799.17	335.36-947.34
	(people per hectare)	SPF	573.32-864.36	394.71-578.08	381.69-552.97	468.56-719.23
		SPDC	90-294	90-294	90-294	90-294
	Mean residential built area: complete dwellings (m^2)		20.64	14.81	12.47	29.53
Final Area Proportions	Built floor area in:	site area (%)	34.22	29.77	17.05*	49.67
		assessable built area (%)	52.13	52.02	59.83*	83.69
	Contemporaneous:	built area in site area (%)	46.89	42.91	40.87	46.16
		residential built area in assessable area (%)	40.45	29.84	28.42	27.83
		built floor area in assessable area (%)	24.44	22.32	21.26	38.63
		residential floor area in assessable area (%)	20.99	14.85	14.14	16.77
	Residential floor area in built floor area (%)		85.88	66.54	66.52	43.4
	Built area in site area (structural density) (%)		65.65	57.21	57.21	59.35

*****Denotes original Subphase B2 proportions replaced by Subphase A2 proportions in calculations.

Appendix B.3: Birch-Chapman, S., Jenkins, E., Coward, F. and Maltby, M., 2017. Estimating population size, density and dynamics of Pre-Pottery Neolithic villages in the central and southern Levant: an analysis of Beidha, southern Jordan. *Levant*, 49(1), 1-23.

Estimating population size, density and dynamics of Pre-Pottery Neolithic villages in the central and southern Levant: an analysis of Beidha, southern Jordan

Shannon Birch-Chapman, Emma Jenkins, Fiona Coward and Mark Maltby[1]

An understanding of population dynamics is essential for reconstructing the trajectories of central and southern Levantine Pre-Pottery Neolithic (PPN) villages. The aim of this investigation was to derive more empirically and statistically robust absolute demographic data than currently exists. Several methodologies were explored, including those based on dwelling unit size and the number of dwellings; residential floor area per person; population density; and allometric growth formulae. The newly established storage provisions formulae based on the affordance of sleeping individuals within structures was found to be the most viable method. Estimates were adjusted to reflect potential structural contemporaneity calculated from building use-life and phase length estimates based on archaeological, ethnographic and experimental research, and Bayesian chronological modelling of radiocarbon dates. The application of methodologies to the PPNB site of Beidha in southern Jordan is presented. The analysis highlights inconsistencies with current theory relating to population density at Beidha. In particular, the results suggest that nuclear families probably did not form the predominant dwelling unit type during Subphases A2 and B2. In addition, population density was estimated at anywhere between 350 and 900 people per ha. This range far exceeds the ethnographically derived density values commonly utilized for reconstructing PPN village populations (*c.* 90 to 294 people per ha).

Keywords Pre-Pottery Neolithic (PPN), Beidha, population estimates, contemporaneity, population density.

Introduction

Absolute estimates of population size, density and dynamics are essential for reconstructing human social development. Population estimates enable more precise explorations of the relationship between groups of people and developments in subsistence, architecture, technology, economic practices, community organization and ritual practices, in all areas and periods. Demographic data is critical for investigating episodes of settlement aggregation, migration and dispersal; and for exploring the underlying causes, processes and consequences of major transitional episodes. Given the pivotal role that the central and southern Levantine Pre-Pottery Neolithic (PPN) played in the Neolithic Demographic Transition (NDT), and the importance of this region for understanding early village development, the methodological and theoretical limitations of existing absolute population estimates of these villages must be addressed.

This investigation assesses existing estimates, methodologies and underlying theories in order to establish a more empirically robust methodological framework for estimating the population size, density and

[1]Department of Archaeology, Anthropology and Forensic Science, Bournemouth University, Poole, UK

Shannon Birch-Chapman (corresponding author), Department of Archaeology, Anthropology and Forensic Science, Bournemouth University, Fern Barrow, Poole, BH12 5BB, UK. Email: SBirch@bournemouth.ac.uk

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Appendix C.1: Site data and micro-level estimates

Nahal Oren

Assessable area (m^2)	Assessable area	326.36
	Unassessable area	-
	Total	**326.36**
Potential residential built area (m^2)	Building 5*	22.98
	Building 8*	10.07
	Building 9*	21.12
	Building 11*	12.32
	Building 12	9.89
	Building 14*	11.88
	Building 16*	23.26
	Building 18	14.16
	Building 19*	10.09
	Building 20*	14.98
	Total	**150.77**
	Mean	15.08
	SD (±)	5.39
	*Mean residential built area: complete dwellings	16.34
Potential non-residential built area (m^2)	Building 7	9.56
	Building 10	8.92
	Building 13	7.63
	Building 19 annex	1.60
	Total	**27.71**
Built area (m^2)	Potential residential built area	150.77
	Potential non-residential built area	27.71
	Total	**178.48**

Potential residential floor area (m^2)	Building 5*	11.33
	Building 8*	6.70
	Building 9*	11.84
	Building 11*	8.06
	Building 12	6.95
	Building 14*	8.00
	Building 16*	14.58
	Building 18	8.68
	Building 19*	6.52
	Building 20*	9.77
	Total	**92.44**
	*Mean residential floor area: complete dwellings	9.60
Built floor area (m^2)	Building 5	11.33
	Building 7	5.72
	Building 8	6.70
	Building 9	11.84
	Building 10	4.47
	Building 11	8.06
	Building 12	6.95
	Building 13	3.79
	Building 14	8.00
	Building 16	14.58
	Building 18	8.68
	Building 19	6.52
	Building 19 annex	0.47
	Building 20	9.77
	Total	**106.90**

Housing unit method (HUM)

Method 1: Total potential dwelling number				**15.31**
Number of potential dwellings in the assessable area				10
Assessable area (m^2)				326.36
Estimated total site extent (m^2)				500
Assessable area (proportion)				0.6527
Method 2: Total potential dwelling number				**15.31**
Mean potential residential built area (m^2)				15.08
Potential residential built area (m^2)	*Building 5*	*22.98*	*Building 14*	*11.88*
	Building 8	*10.07*	*Building 16*	*23.26*
	Building 9	*21.11*	*Building 18*	*14.15*
	Building 11	*12.32*	*Building 19*	*10.09*
	Building 12	*9.89*	*Building 20*	*14.98*
Total built area estimate (m^2)				273.44
			Assessable area (m^2)	*326.36*
			Assessable built area (m^2)	*178.48*
			Assessable built area as a proportion of assessable area	*0.5469*
			Estimated total site extent (m^2)	*500*
Residential built area as a proportion of assessable built area				0.8446
			Potential residential built area (m^2)	*150.74*
Total potential residential built area (m^2)				230.94
Method 3: Total potential dwelling number				**15.31**
Potential residential built area as a proportion of assessable area				0.4619
Total number of contemporaneous dwellings (80%)				12.25
Total population estimate based on nuclear family size:	**Minimum**	**3**		**36.74**
	Average	**5.5**		**67.36**
	Maximum	**8**		**97.98**

Residential area density coefficient (RADC)

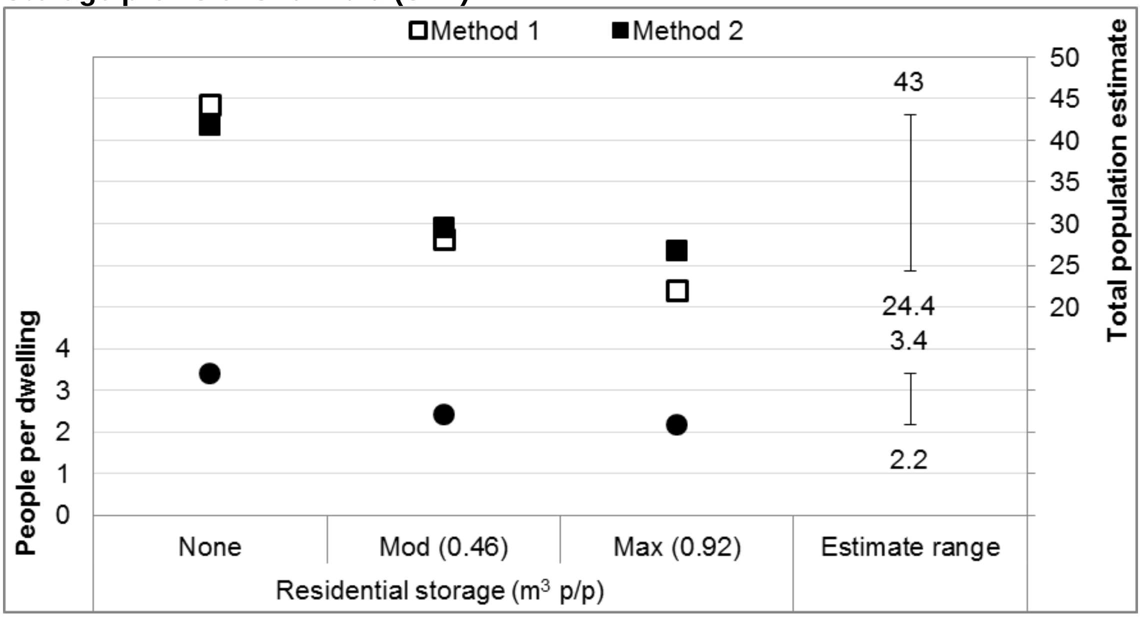
Method 1: Total potential residential floor area (m^2)				**141.62**
Potential residential floor area (m^2)				92.44
Potential residential floor area (m^2)	*Building 5*	*11.33*	*Building 14*	*8.00*
	Building 8	*6.70*	*Building 16*	*14.58*
	Building 9	*11.84*	*Building 18*	*8.68*
	Building 11	*8.06*	*Building 19*	*6.52*
	Building 12	*6.95*	*Building 20*	*9.77*
Assessable area (m^2)				326.36
Estimated total site extent (m^2)				500
Assessable area (proportion)				0.6527

Method 2: Total potential residential floor area (m^2)	**141.62**
Total built area estimate (m^2)	273.44
Assessable area (m^2)	*326.36*
Assessable built area (m^2)	*178.48*
Assessable built area as a proportion of assessable area	*0.5469*
Estimated total site extent (m^2)	*500*
Potential residential floor area as a proportion of assessable built area	0.5179
Potential residential floor area (m^2)	*92.44*

Method 3: Total potential residential floor area (m^2)	**141.62**
Potential residential floor area as a proportion of assessable area	0.2832
Total contemporaneous residential floor area (m^2) (80%)	113.30

Total population estimate based on RADC (m^2):	**Minimum**	**1.77**	**64.01**
	Average	**3.3**	**34.33**
	Maximum	**5**	**22.66**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None			*Moderate (0.46)*			*Maximum (2 x 0.46)*		
			P = 0.3944A – 0.375			*P = 0.2477A + 0.0339*			*P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	113.30	0.3944 x 113.3	=	44.69	0.2477 x 113.3	=	28.06	0.1903 x 113.3	=	21.56
P	=	?	44.69 - 0.375	=	44.31	28.06 + 0.0339	=	28.10	21.56 + 0.3976	=	21.96
			P	**=**	**44.31**	**P**	**=**	**28.10**	**P**	**=**	**21.96**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	9.6	0.3944 x 9.6	=	3.79	0.2477 x 9.6	=	2.38	0.1903 x 9.6	=	1.83
P	=	?	3.79 - 0.375	=	3.41	2.38 + 0.0339	=	2.41	1.83 + 0.3976	=	2.19
			P	**=**	**3.41**	**P**	**=**	**2.41**	**P**	**=**	**2.19**
						Total number of contemporaneous dwellings					*12.25*
		Total population			**41.79**			**29.54**			**26.78**
Mean total population					**43.05**			**28.82**			**24.37**

Naroll’s (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (43.05)	*Moderate (28.82)*	*Maximum (24.37)*		*None (43.05)*	*Moderate (28.82)*	*Maximum (24.37)*
Total built floor area (m^2)	515.44	367.68	319.24	163.78			
Built floor area per person (m^2)	11.97	12.76	13.10		3.80	5.68	6.72
RADC (m^2 per person)	10.35	11.03	11.33		2.63	3.93	4.65
Initial growth index	6.90	9.67	11.13				

Data required		
SPF population estimate (P) based on amount of storage:	None	43.05
	Moderate	28.82
	Maximum	24.37
Residential floor area as a proportion of built floor area (%)		86.47
Total built floor area (m^2) (A)		*163.78*
Built floor area in assessable area (m^2)		*106.90*
Proportion of site assessable (%)		*65.27*
Total residential floor area (m^2) (RADC method)		*141.62*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	3.80
	Moderate	5.68
	Maximum	6.72
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.63
	Moderate	3.93
	Maximum	4.65
Total contemporaneous residential floor area (m^2) (RADC method)		113.30

$A = a \times P^b$

Amount of storage:							
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?		**$A = 21.7 \times 43.05^{0.84195}$**		
	P	=	43.05	$43.05^{0.84195}$		=	23.75
	a	=	21.7	21.7 x 23.75		=	515.44
	b	=	0.84195	**A**		**=**	**515.44**
	Built floor area per person (m^2)						**11.97**
	RADC (m^2 per person)						**10.35**
				Residential floor area as a proportion of built floor area			*86.47*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	163.78		**$163.78 = a \times 43.05^{0.84195}$**		
	P	=	43.05	$43.05^{0.84195}$		=	23.75
	a	=	?	163.78/23.75		=	6.90
	b	=	0.84195	***a***		**=**	**6.90**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?		**$A = 21.7 \times 28.82^{0.84195}$**		
	P	=	28.82	$28.82^{0.84195}$		=	16.94
	a	=	21.7	21.7 x 16.94		=	367.68
	b	=	0.84195	**A**		**=**	**367.68**
	Built floor area per person (m^2)						**12.76**
	RADC (m^2 per person)						**11.03**
				Residential floor area as a proportion of built floor area			*86.47*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	163.78		**$163.78 = a \times 28.82^{0.84195}$**		
	P	=	28.82	$28.82^{0.84195}$		=	16.94
	a	=	?	163.78/16.94		=	9.67
	b	=	0.84195	***a***		**=**	**9.67**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?		**$A = 21.7 \times 24.37^{0.84195}$**		
	P	=	24.37	$24.37^{0.84195}$		=	14.71
	a	=	21.7	21.7 x 14.71		=	319.24
	b	=	0.84195	**A**		**=**	**319.24**
	Built floor area per person (m^2)						**13.10**
	RADC (m^2 per person)						**11.33**
				Residential floor area as a proportion of built floor area			*86.47*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	163.78		**$163.78 = a \times 24.37^{0.84195}$**		
	P	=	24.37	$24.37^{0.84195}$		=	14.71
	a	=	?	163.78/14.71		=	11.13
	b	=	0.84195	***a***		**=**	**11.13**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		500
SPF population estimate (P) based on amount of storage:	None	43.05
	Moderate	28.82
	Maximum	24.37

$A = a \times P^b$

Amount of storage:							
None	**Open settlements**				**$500 = a \times 43.05^2$**		
	A	=	500				
	P	=	43.05	43.05^2		=	1853.23
	a	=	?	500/1853.23		=	0.27
	b	=	2	***a***		**=**	**0.27**
	Village settlements				**$500 = a \times 43.05^1$**		
	A	=	500				
	P	=	43.05	43.05^1		=	43.05
	a	=	?	500/43.05		=	11.6
	b	=	1	***a***		**=**	**11.6**
	Urban settlements				**$500 = a \times 43.05^{0.6667}$**		
	A	=	500				
	P	=	43.05	$43.05^{0.6667}$		=	12.28
	a	=	?	500/12.28		=	40.70
	b	=	0.6667	***a***		**=**	**40.70**
Moderate	**Open settlements**				**$500 = a \times 28.82^2$**		
	A	=	500				
	P	=	28.82	28.82^2		=	830.68
	a	=	?	500/830.68		=	0.60
	b	=	2	***a***		**=**	**0.60**
	Village settlements				**$500 = a \times 28.82^1$**		
	A	=	500				
	P	=	28.82	28.82^1		=	28.82
	a	=	?	500/28.82		=	17.3
	b	=	1	***a***		**=**	**17.3**
	Urban settlements				**$500 = a \times 28.82^{0.6667}$**		
	A	=	500				
	P	=	28.82	$28.82^{0.6667}$		=	9.40
	a	=	?	500/9.4		=	53.18
	b	=	0.6667	***a***		**=**	**53.18**
Maximum	**Open settlements**				**$500 = a \times 24.37^2$**		
	A	=	500				
	P	=	24.37	24.37^2		=	593.88
	a	=	?	500/593.88		=	0.84
	b	=	2	***a***		**=**	**0.84**
	Village settlements				**$500 = a \times 24.37^1$**		
	A	=	500				
	P	=	24.37	24.37^1		=	24.37
	a	=	?	500/24.37		=	20.5
	b	=	1	***a***		**=**	**20.5**
	Urban settlements				**$500 = a \times 24.37^{0.6667}$**		
	A	=	500				
	P	=	24.37	$24.37^{0.6667}$		=	8.41
	a	=	?	500/8.41		=	59.48
	b	=	0.6667	***a***		**=**	**59.48**

Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (43.05)	*Moderate (28.82)*	*Maximum (24.37)*
Open	0.27	0.60	0.84
Village	11.61	17.35	20.52
Urban	40.70	53.18	59.48

Settlement population density coefficient (SPDC)

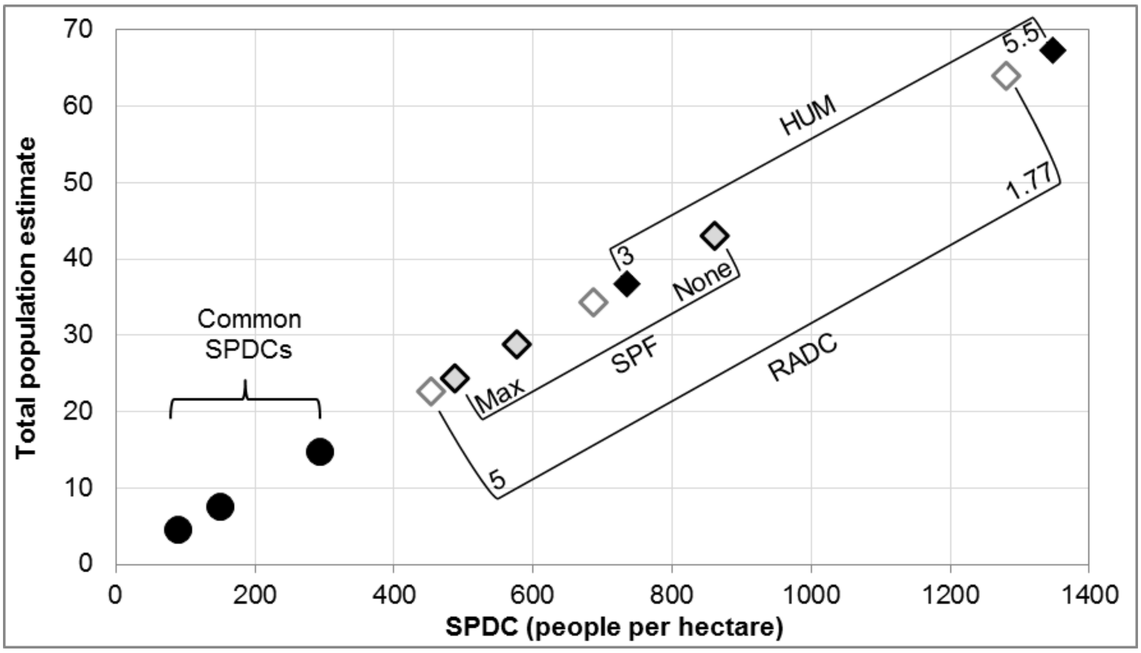
Data required	
Total site extent (ha)	0.05
Proportion of site assessable (%)	65.27
Number of contemporaneous dwellings in the assessable area	8.00
Dwellings in assessable area	*10*
Contemporaneity value (%)	*80*

Method 1: Total population based on commonly utilised SPDCs

	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	4.5	7.5	14.7
Population in the assessable area	*2.94*	*4.90*	*9.59*
People per dwelling in the assessable area	*0.37*	*0.61*	*1.20*

Method 2: SPDCs based on HUM, RADC and SPF population estimates

Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	36.74	-	67.36	734.80	-	1347.20
RADC	22.66	34.33	64.01	453.19	686.66	1280.21
SPF	24.37	28.82	43.05	487.39	576.43	860.98



Gilgal I

Assessable area (m^2)	Assessable area	214.66
	Unassessable area	-
	Total	**214.66**
Potential residential built area (m^2)	Locus 3*	22.17
	Locus 4*	14.59
	Locus 5	7.10
	Locus 7*	14.15
	Locus 10*	12.89
	Locus 12	4.11
	Total	**75.01**
	Mean	12.50
	SD (±)	6.33
	*Mean residential built area: complete dwellings	15.95
Potential non-residential built area (m^2)	Locus 6	2.20
	Locus 8	5.20
	Locus 11	21.78
	Locus 13	3.50
	Locus 14	2.62
	Total	**35.30**
Built area (m^2)	Potential residential built area	75.01
	Potential non-residential built area	35.30
	Total	**110.31**

Potential residential floor area (m^2)	Locus 3*	18.42
	Locus 4*	11.36
	Locus 5	5.09
	Locus 7*	10.70
	Locus 10*	10.61
	Locus 12	3.14
	Total	**59.31**
	*Mean residential floor area: complete dwellings	12.77
Built floor area (m^2)	Locus 3	18.42
	Locus 4	11.36
	Locus 5	5.09
	Locus 6	1.20
	Locus 7	10.70
	Locus 8	3.91
	Locus 10	10.61
	Locus 11	18.20
	Locus 12	3.14
	Locus 13	1.62
	Locus 14	1.64
	Total	**85.89**

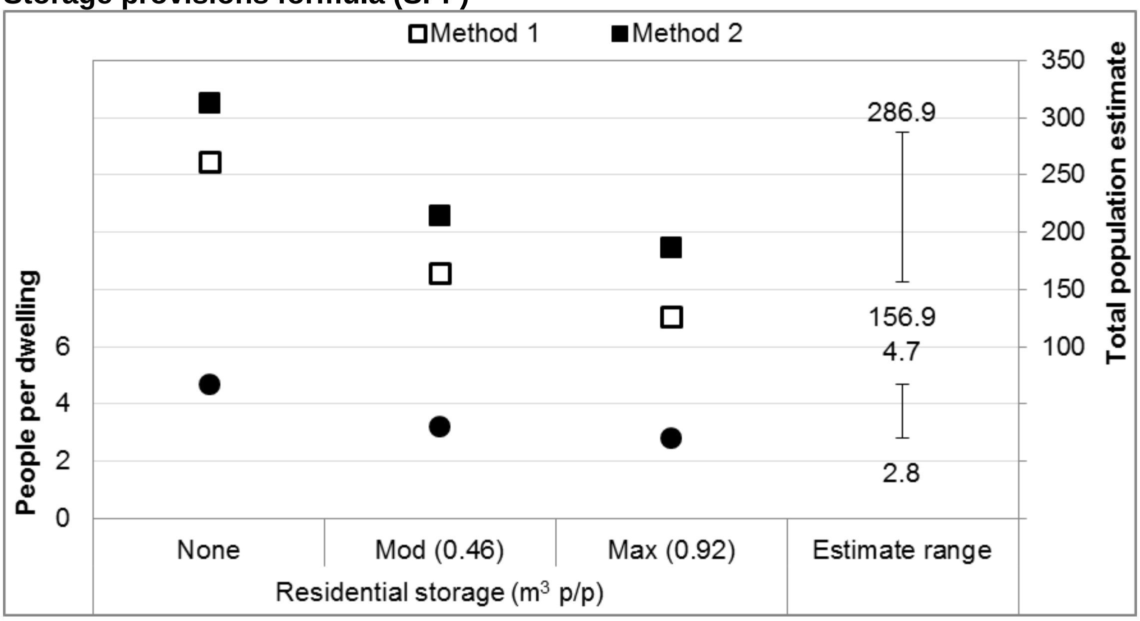
Housing unit method (HUM)

Method 1: Total potential dwelling number					**111.80**
Number of potential dwellings in the assessable area					6
Assessable area (m^2)					214.66
Estimated total site extent (m^2)					4000
Assessable area (proportion)					0.0537
Method 2: Total potential dwelling number					**111.80**
Mean potential residential built area (m^2)					12.50
Potential residential built area (m^2)	*Locus 3*	*22.17*	*Locus 7*		*14.15*
	Locus 4	*14.59*	*Locus 10*		*12.89*
	Locus 5	*7.10*	*Locus 12*		*4.11*
Total built area estimate (m^2)					2055.53
				Assessable area (m^2)	*214.66*
				Assessable built area (m^2)	*110.31*
				Assessable built area as a proportion of assessable area	*0.5139*
				Estimated total site extent (m^2)	*4000*
Residential built area as a proportion of assessable built area					0.6800
				Potential residential built area (m^2)	*75.01*
Total potential residential built area (m^2)					1397.75
Method 3: Total potential dwelling number					**111.80**
Potential residential built area as a proportion of assessable area					0.3494
Total number of contemporaneous dwellings (60%)					67.08
Total population estimate based on nuclear family size:	**Minimum**	**3**			**201.25**
	Average	**5.5**			**368.96**
	Maximum	**8**			**536.66**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)				**1105.27**
Potential residential floor area (m^2)				59.31
Potential residential floor area (m^2)	*Locus 3*	*18.42*	*Locus 7*	*10.70*
	Locus 4	*11.36*	*Locus 10*	*10.61*
	Locus 5	*5.09*	*Locus 12*	*3.14*
Assessable area (m^2)				214.66
Estimated total site extent (m^2)				4000
Assessable area (proportion)				0.0537
Method 2: Total potential residential floor area (m^2)				**1105.27**
Total built area estimate (m^2)				2055.53
			Assessable area (m^2)	*214.66*
			Assessable built area (m^2)	*110.31*
			Assessable built area as a proportion of assessable area	*0.5139*
			Estimated total site extent (m^2)	*4000*
Potential residential floor area as a proportion of assessable built area				0.5377
			Potential residential floor area (m^2)	*59.31*
Method 3: Total potential residential floor area (m^2)				**1105.27**
Potential residential floor area as a proportion of assessable area				0.2763
Total contemporaneous residential floor area (m^2) (60%)				663.16
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**		**374.67**
	Average	**3.3**		**200.96**
	Maximum	**5**		**132.63**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	663.16	0.3944 x 663.16	=	261.55	0.2477 x 663.16	=	164.26	0.1903 x 663.16	=	126.20
P	=	?	261.55 - 0.375	=	261.18	164.26 + 0.0339	=	164.30	126.2 + 0.3976	=	126.60
			P	**=**	**261.18**	**P**	**=**	**164.30**	**P**	**=**	**126.60**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	12.77	0.3944 x 12.77	=	5.04	0.2477 x 12.77	=	3.16	0.1903 x 12.77	=	2.43
P	=	?	5.04 - 0.375	=	4.66	3.16 + 0.0339	=	3.20	2.43 + 0.3976	=	2.79
			P	**=**	**4.66**	**P**	**=**	**3.20**	**P**	**=**	**2.79**
						Total number of contemporaneous dwellings					*67.08*
		Total population			**312.69**			**214.46**			**187.12**
Mean total population					**286.93**			**189.38**			**156.86**

Naroll's (1962) AGF1

Summary of estimates based on:	Naroll's (1962) formula				Archaeological evidence		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (286.93)	*Moderate (189.38)*	*Maximum (156.86)*		*None (286.93)*	*Moderate (189.38)*	*Maximum (156.86)*
Total built floor area (m^2)	2545.59	1794.14	1530.95	1599.44			
Built floor area per person (m^2)	8.87	9.47	9.76		5.57	8.45	10.20
RADC (m^2 per person)	6.13	6.55	6.74		2.31	3.50	4.23
Initial growth index	13.63	19.35	22.67				

Data required		
SPF population estimate (P) based on amount of storage:	None	286.93
	Moderate	189.38
	Maximum	156.86
Residential floor area as a proportion of built floor area (%)		69.10
Total built floor area (m^2) (A)		*1599.44*
Built floor area in assessable area (m^2)		*85.89*
Proportion of site assessable (%)		*5.37*
Total residential floor area (m^2) (RADC method)		*1105.27*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	5.57
	Moderate	8.45
	Maximum	10.20
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.31
	Moderate	3.50
	Maximum	4.23
Total contemporaneous residential floor area (m^2) (RADC method)		663.16

Amount of storage:		$A = a \times P^b$					
	None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 286.93^{0.84195}$**		
		P	=	286.93	$286.93^{0.84195}$	=	117.31
		a	=	21.7	21.7 x 117.31	=	2545.59
		b	=	0.84195	**A**	**=**	**2545.59**
		Built floor area per person (m^2)					**8.87**
		RADC (m^2 per person)					**6.13**
					Residential floor area as a proportion of built floor area		*69.10*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1599.44	**$1599.44 = a \times 286.93^{0.84195}$**		
		P	=	286.93	$286.93^{0.84195}$	=	117.31
		a	=	?	1599.44/117.31	=	13.63
		b	=	0.84195	***a***	**=**	**13.63**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 189.38^{0.84195}$**		
		P	=	189.38	$189.38^{0.84195}$	=	82.68
		a	=	21.7	21.7 x 82.68	=	1794.14
		b	=	0.84195	**A**	**=**	**1794.14**
		Built floor area per person (m^2)					**9.47**
		RADC (m^2 per person)					**6.55**
					Residential floor area as a proportion of built floor area		*69.10*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1599.44	**$1599.44 = a \times 189.38^{0.84195}$**		
		P	=	189.38	$189.38^{0.84195}$	=	82.68
		a	=	?	1599.44/82.68	=	19.35
		b	=	0.84195	***a***	**=**	**19.35**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 156.86^{0.84195}$**		
		P	=	156.86	$156.86^{0.84195}$	=	70.55
		a	=	21.7	21.7 x 70.55	=	1530.95
		b	=	0.84195	**A**	**=**	**1530.95**
		Built floor area per person (m^2)					**9.76**
		RADC (m^2 per person)					**6.74**
					Residential floor area as a proportion of built floor area		*69.10*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1599.44	**$1599.44 = a \times 156.86^{0.84195}$**		
		P	=	156.86	$156.86^{0.84195}$	=	70.55
		a	=	?	1599.44/70.55	=	22.67
		b	=	0.84195	***a***	**=**	**22.67**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		4000
SPF population estimate (P) based on amount of storage:	None	286.93
	Moderate	189.38
	Maximum	156.86

Amount of storage:					**$A = a \times P^b$**		
None	**Open settlements**				**$4000 = a \times 286.93^2$**		
	A	=	4000				
	P	=	286.93	286.93^2		=	82331.10
	a	=	?	4000/82331.1		=	0.05
	b	=	2	***a***		**=**	**0.05**
	Village settlements				**$4000 = a \times 286.93^1$**		
	A	=	4000				
	P	=	286.93	286.93^1		=	286.93
	a	=	?	4000/286.93		=	13.9
	b	=	1	***a***		**=**	**13.9**
	Urban settlements				**$4000 = a \times 286.93^{.6667}$**		
	A	=	4000				
	P	=	286.93	$286.93^{0.6667}$		=	43.51
	a	=	?	4000/43.51		=	91.93
	b	=	0.6667	***a***		**=**	**91.93**
Moderate	**Open settlements**				**$4000 = a \times 189.38^2$**		
	A	=	4000				
	P	=	189.38	189.38^2		=	35863.90
	a	=	?	4000/35864.78		=	0.11
	b	=	2	***a***		**=**	**0.11**
	Village settlements				**$4000 = a \times 189.38^1$**		
	A	=	4000				
	P	=	189.38	189.38^1		=	189.38
	a	=	?	4000/189.38		=	21.1
	b	=	1	***a***		**=**	**21.1**
	Urban settlements				**$4000 = a \times 189.38^{0.6667}$**		
	A	=	4000				
	P	=	189.38	$189.38^{0.6667}$		=	32.98
	a	=	?	4000/32.98		=	121.27
	b	=	0.6667	***a***		**=**	**121.27**
Maximum	**Open settlements**				**$4000 = a \times 156.86^2$**		
	A	=	4000				
	P	=	156.86	156.86^2		=	24603.80
	a	=	?	4000/24603.8		=	0.16
	b	=	2	***a***		**=**	**0.16**
	Village settlements				**$4000 = a \times 156.86^1$**		
	A	=	4000				
	P	=	156.86	156.86^1		=	156.86
	a	=	?	4000/156.86		=	25.5
	b	=	1	***a***		**=**	**25.5**
	Urban settlements				**$4000 = a \times 156.86^{0.6667}$**		
	A	=	4000				
	P	=	156.86	$156.86^{0.6667}$		=	29.09
	a	=	?	4000/29.09		=	137.51
	b	=	0.6667	***a***		**=**	**137.51**

Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (286.93)	*Moderate (189.38)*	*Maximum (156.86)*
Open	0.05	0.11	0.16
Village	13.94	21.12	25.50
Urban	91.93	121.27	137.51

Settlement population density coefficient (SPDC)

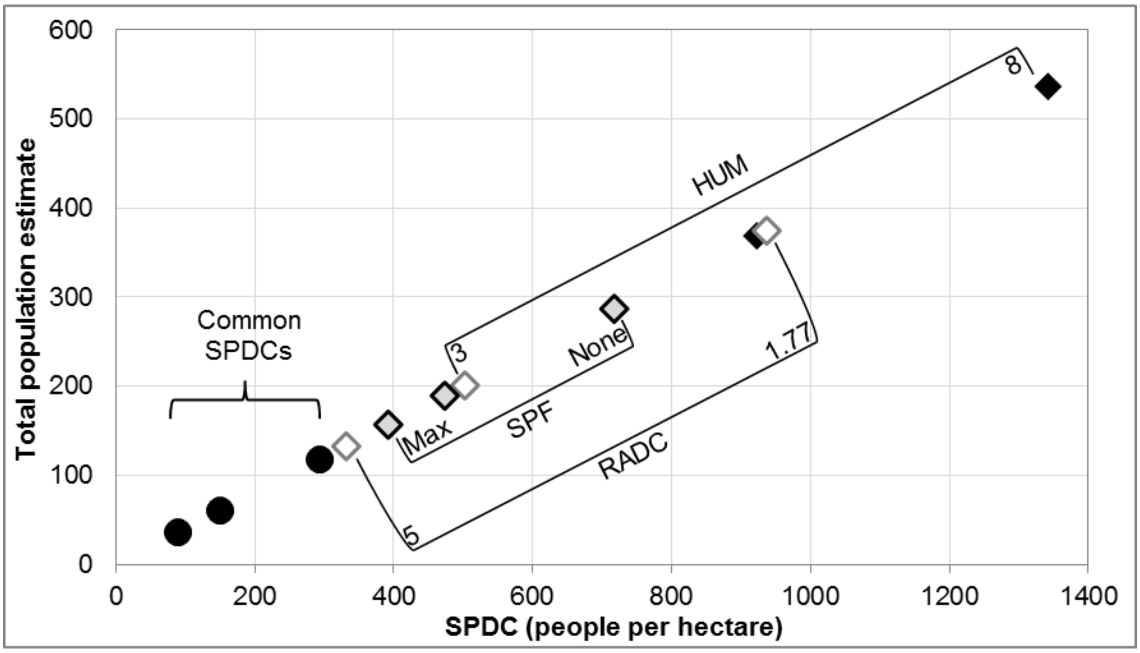
Data required	
Total site extent (ha)	0.4
Proportion of site assessable (%)	5.37
Number of contemporaneous dwellings in the assessable area	3.60
Dwellings in assessable area	*6*
Contemporaneity value (%)	*60*

Method 1: Total population based on commonly utilised SPDCs

	SPDC (people/ha)		
	Minimum 90	*Average 150*	*Maximum 294*
Total population	36	60	117.6
Population in the assessable area	*1.93*	*3.22*	*6.32*
People per dwelling in the assessable area	*0.54*	*0.90*	*1.75*

Method 2: SPDCs based on HUM, RADC and SPF population estimates

Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	201.25	368.96	536.66	503.12	922.39	1341.66
RADC	132.63	200.96	374.67	331.58	502.39	936.67
SPF	156.86	189.38	286.93	392.14	473.44	717.33



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Assessable area (m^2)	Assessable area	533.82
	Unassessable area	-
	Total	**533.82**
Potential residential built area (m^2)	Locus 8	31.49
	Locus 9	27.97
	Locus 10	27.58
	Locus 20	25.44
	Locus 22	22.33
	Locus 30	34.42
	Total	**169.23**
	Mean	28.21
	SD (±)	4.29
	Mean residential built area (all complete)	28.21
Built area (m^2)	Potential residential built area	169.23
	Potential non-residential built area	-
	Total	**169.23**

Potential residential floor area (m^2)	Locus 8	23.63
	Locus 9	22.47
	Locus 10	21.74
	Locus 20	20.40
	Locus 22	16.01
	Locus 30	23.74
	Total	**127.99**
	Mean residential floor area (all complete)	21.33
Built floor area (m^2)	Locus 8	23.63
	Locus 9	22.47
	Locus 10	21.74
	Locus 20	20.40
	Locus 22	16.01
	Locus 30	23.74
	Total	**127.99**

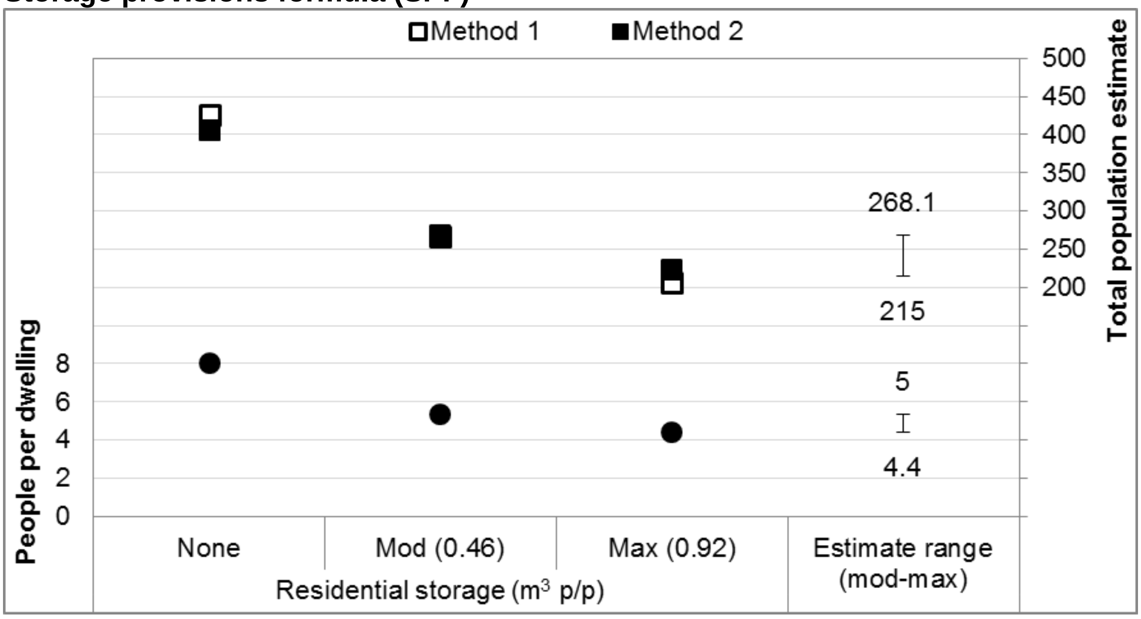
Housing unit method (HUM)

Method 1: Total potential dwelling number					**84.30**
Number of potential dwellings in the assessable area					6
Assessable area (m^2)					533.82
Estimated total site extent (m^2)					7500
Assessable area (proportion)					0.0712
Method 2: Total potential dwelling number					**84.30**
Mean potential residential built area (m^2)					28.21
Potential residential built area (m^2)	*Locus 8*	*31.49*	*Locus 20*		*25.44*
	Locus 9	*27.97*	*Locus 22*		*22.33*
	Locus 10	*27.58*	*Locus 30*		*34.42*
Total built area estimate (m^2)					2377.63
				Assessable area (m^2)	*533.82*
				Assessable built area (m^2)	*169.23*
				Assessable built area as a proportion of assessable area	*0.3170*
				Estimated total site extent (m^2)	*7500*
Residential built area as a proportion of assessable built area					1.0000
				Potential residential built area (m^2)	*169.23*
Total potential residential built area (m^2)					2377.63
Method 3: Total potential dwelling number					**84.30**
Potential residential built area as a proportion of assessable area					0.3170
Total number of contemporaneous dwellings (60%)					50.58
Total population estimate based on nuclear family size:	**Minimum**	**3**			**151.74**
	Average	**5.5**			**278.18**
	Maximum	**8**			**404.63**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)				**1798.22**
Potential residential floor area (m^2)				127.99
Potential residential floor area (m^2)	*Locus 8*	*23.63*	*Locus 20*	*20.40*
	Locus 9	*22.47*	*Locus 22*	*16.01*
	Locus 10	*21.74*	*Locus 30*	*23.74*
Assessable area (m^2)				533.82
Estimated total site extent (m^2)				7500
Assessable area (proportion)				0.0712
Method 2: Total potential residential floor area (m^2)				**1798.22**
Total built area estimate (m^2)				2377.63
			Assessable area (m^2)	*533.82*
			Assessable built area (m^2)	*169.23*
			Assessable built area as a proportion of assessable area	*0.3170*
			Estimated total site extent (m^2)	*7500*
Potential residential floor area as a proportion of assessable built area				0.7563
			Potential residential floor area (m^2)	*127.99*
Method 3: Total potential residential floor area (m^2)				**1798.22**
Potential residential floor area as a proportion of assessable area				0.2398
Total contemporaneous residential floor area (m^2) (60%)				1078.93
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**		**609.57**
	Average	**3.3**		**326.95**
	Maximum	**5**		**215.79**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None			*Moderate (0.46)*			*Maximum (2 x 0.46)*		
			P = 0.3944A – 0.375			*P = 0.2477A + 0.0339*			*P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	1078.93	0.3944 x 1078.93	=	425.53	0.2477 x 1078.93	=	267.25	0.1903 x 1078.93	=	205.32
P	=	?	425.53 - 0.375	=	425.16	267.25 + 0.0339	=	267.29	205.32 + 0.3976	=	205.72
			P	**=**	**425.16**	**P**	**=**	**267.29**	**P**	**=**	**205.72**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	21.33	0.3944 x 21.33	=	8.41	0.2477 x 21.33	=	5.28	0.1903 x 21.33	=	4.06
P	=	?	8.41 - 0.375	=	8.04	5.28 + 0.0339	=	5.32	4.06 + 0.3976	=	4.42
			P	**=**	**8.04**	**P**	**=**	**5.32**	**P**	**=**	**4.42**
						Total number of contemporaneous dwellings					*50.58*
		Total population			**406.54**			**268.95**			**223.48**
Mean total population					**415.85**			**268.1**			**214.6**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**			**Archaeological evidence**			
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (415.85)	Moderate (268.12)	*Maximum (214.6)*		*None (415.85)*	*Moderate (268.12)*	*Maximum (214.6)*
Total built floor area (m^2)	3479.13	2404.30	1993.32	1798.22			
Built floor area per person (m^2)	8.37	8.97	9.29		4.32	6.71	8.38
RADC (m^2 per person)	8.37	8.97	9.29		2.59	4.02	5.03
Initial growth index	11.22	16.23	19.58				

Data required		
SPF population estimate (P) based on amount of storage:	None	415.85
	Moderate	268.12
	Maximum	214.60
Residential floor area as a proportion of built floor area (%)		100.00
Total built floor area (m^2) (A)		*1798.22*
Built floor area in assessable area (m^2)		*127.99*
Proportion of site assessable (%)		*7.12*
Total residential floor area (m^2) (RADC method)		*1798.22*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	4.32
	Moderate	6.71
	Maximum	8.38
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.59
	Moderate	4.02
	Maximum	5.03
Total contemporaneous residential floor area (m^2) (RADC method)		1078.93

Amount of storage:		$A = a \times P^b$					
	None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 415.85^{0.84195}$**		
		P	=	415.85	$415.85^{0.84195}$	=	160.33
		a	=	21.7	21.7 x 160.33	=	3479.13
		b	=	0.84195	**A**	**=**	**3479.13**
		Built floor area per person (m^2)					**8.37**
		RADC (m^2 per person)					**8.37**
					Residential floor area as a proportion of built floor area		*100.00*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1798.22	**$1798.22 = a \times 415.85^{0.84195}$**		
		P	=	415.85	$415.85^{0.84195}$	=	160.33
		a	=	?	1798.22/160.33	=	11.22
		b	=	0.84195	***a***	**=**	**11.22**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 268.12^{0.84195}$**		
		P	=	268.12	$268.12^{0.84195}$	=	110.80
		a	=	21.7	21.7 x 110.8	=	2404.30
		b	=	0.84195	**A**	**=**	**2404.30**
		Built floor area per person (m^2)					**8.97**
		RADC (m^2 per person)					**8.97**
					Residential floor area as a proportion of built floor area		*100.00*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1798.22	**$1798.22 = a \times 268.12^{0.84195}$**		
		P	=	268.12	$268.12^{0.84195}$	=	110.80
		a	=	?	1798.22/110.8	=	16.23
		b	=	0.84195	***a***	**=**	**16.23**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 214.6^{0.84195}$**		
		P	=	214.60	$214.6^{0.84195}$	=	91.86
		a	=	21.7	21.7 x 91.86	=	1993.32
		b	=	0.84195	**A**	**=**	**1993.32**
		Built floor area per person (m^2)					**9.29**
		RADC (m^2 per person)					**9.29**
					Residential floor area as a proportion of built floor area		*100.00*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	1798.22	**$1798.22 = a \times 214.6^{0.84195}$**		
		P	=	214.60	$214.6^{0.84195}$	=	91.86
		a	=	?	1798.22/91.86	=	19.58
		b	=	0.84195	***a***	**=**	**19.58**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		7500
SPF population estimate (P) based on amount of storage:	None	415.85
	Moderate	268.12
	Maximum	214.60

$$A = a \times P^b$$

Amount of storage:						
None	**Open settlements**			**$7500 = a \times 415.85^2$**		
	A	=	7500			
	P	=	415.85	415.85^2	=	172929.06
	a	=	?	7500/172929.06	=	0.04
	b	=	2	***a***	**=**	**0.04**
	Village settlements			**$7500 = a \times 415.85^1$**		
	A	=	7500			
	P	=	415.85	415.85^1	=	415.85
	a	=	?	7500/415.85	=	18.04
	b	=	1	***a***	**=**	**18.04**
	Urban settlements			**$7500 = a \times 415.85^{0.6667}$**		
	A	=	7500			
	P	=	415.85	$415.85^{0.6667}$	=	55.72
	a	=	?	7500/55.72	=	134.59
	b	=	0.6667	***a***	**=**	**134.59**
Moderate	**Open settlements**			**$7500 = a \times 268.12^2$**		
	A	=	7500			
	P	=	268.12	268.12^2	=	71887.33
	a	=	?	7500/71887.33	=	0.10
	b	=	2	***a***	**=**	**0.10**
	Village settlements			**$7500 = a \times 268.12^1$**		
	A	=	7500			
	P	=	268.12	268.12^1	=	268.12
	a	=	?	7500/268.12	=	27.97
	b	=	1	***a***	**=**	**27.97**
	Urban settlements			**$7500 = a \times 268.12^{0.6667}$**		
	A	=	7500			
	P	=	268.12	$268.12^{0.6667}$	=	41.59
	a	=	?	7500/41.59	=	180.34
	b	=	0.6667	***a***	**=**	**180.34**
Maximum	**Open settlements**			**$7500 = a \times 214.6^2$**		
	A	=	7500			
	P	=	214.60	214.6^2	=	46053.33
	a	=	?	7500/46053.33	=	0.16
	b	=	2	***a***	**=**	**0.16**
	Village settlements			**$7500 = a \times 214.6^1$**		
	A	=	7500			
	P	=	214.60	214.6^1	=	214.60
	a	=	?	7500/214.6	=	34.95
	b	=	1	***a***	**=**	**34.95**
	Urban settlements			**$7500 = a \times 214.6^{0.6667}$**		
	A	=	7500			
	P	=	214.60	$214.6^{0.6667}$	=	35.85
	a	=	?	7500/35.85	=	209.20
	b	=	0.6667	***a***	**=**	**209.20**

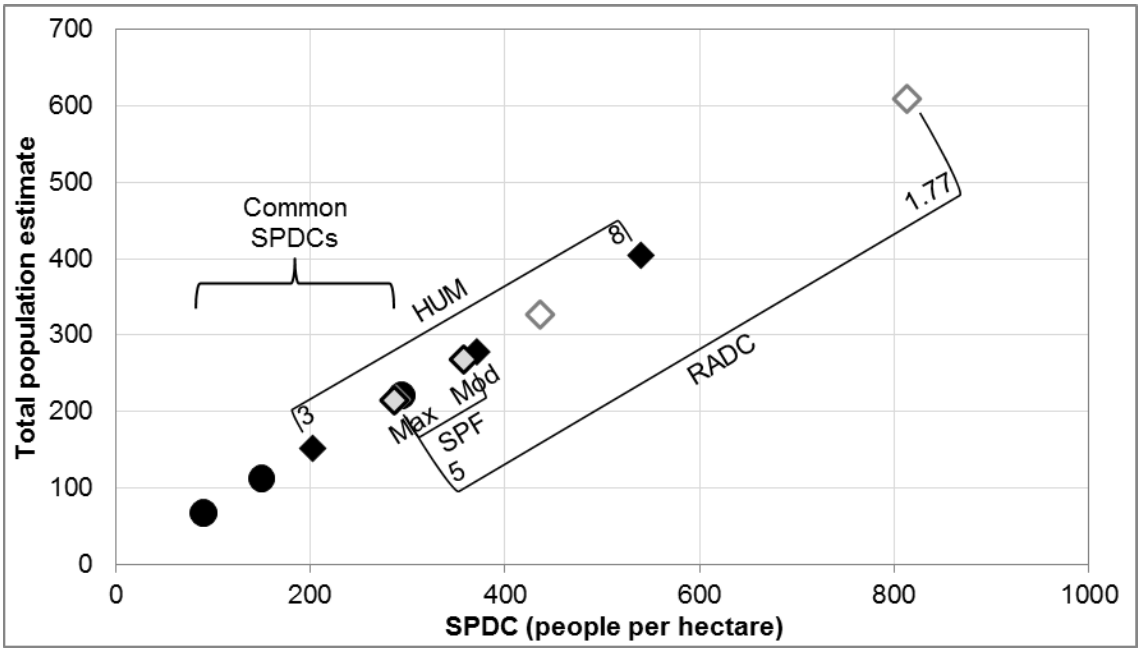
Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (415.85)	*Moderate (268.12)*	*Maximum (214.6)*
Open	0.04	0.10	0.16
Village	18.04	27.97	34.95
Urban	134.59	180.34	209.20

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	0.75
Proportion of site assessable (%)	7.12
Number of contemporaneous dwellings in the assessable area	3.60
Dwellings in assessable area	*6*
Contemporaneity value (%)	*60*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	67.5	112.5	220.5
Population in the assessable area	*4.80*	*8.01*	*15.69*
People per dwelling in the assessable area	*1.33*	*2.22*	*4.36*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	151.74	278.18	404.63	202.32	370.91	539.51
RADC	215.79	326.95	609.57	287.71	435.93	812.75
SPF	214.60	-	268.12	286.13	-	357.49



El-Hemmeh (PPNA)

Assessable area (m^2)	Assessable area	80.12
	Unassessable area	18.63
	Total	**61.49**
Potential residential built area (m^2)	Structure 1	3.22
	Structure 2*	6.80
	Structure 3	3.68
	Structure 4	4.80
	Structure 5	2.59
	Structure 10*	8.32
	Total	**29.41**
	Mean	4.90
	SD (±)	2.23
	*Mean residential built area: complete dwellings	7.56
Potential non-residential built area (m^2)	Structure 8	4.24
	Total	**4.24**
Built area (m^2)	Potential residential built area	29.41
	Potential non-residential built area	4.24
	Total	**33.65**

Potential residential floor area (m^2)	Structure 1	1.89
	Structure 2*	3.93
	Structure 3	2.54
	Structure 4	3.13
	Structure 5	1.42
	Structure 10*	5.72
	Total	**18.64**
	*Mean residential floor area: complete dwellings	4.83
Built floor area (m^2)	Structure 1	1.89
	Structure 2	3.93
	Structure 3	2.54
	Structure 4	3.13
	Structure 5	1.42
	Structure 8	2.62
	Structure 10	5.72
	Total	**21.26**

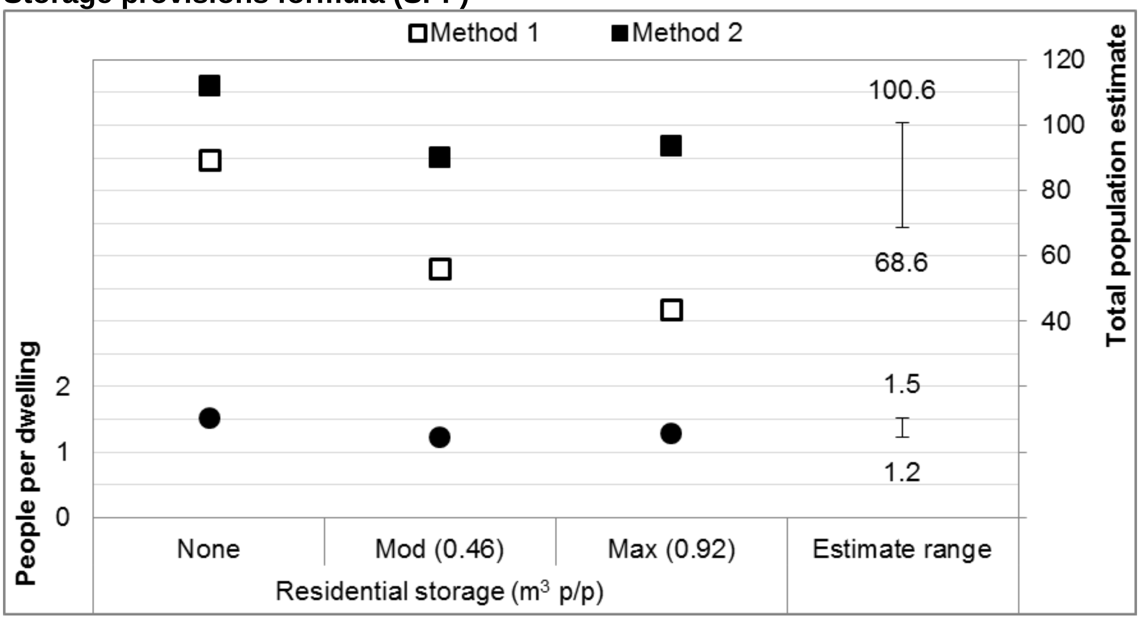
Housing unit method (HUM)

Method 1: Total potential dwelling number				**97.58**
Number of potential dwellings in the assessable area				6
Assessable area (m^2)				61.49
Estimated total site extent (m^2)				1000
Assessable area (proportion)				0.0615
Method 2: Total potential dwelling number				**97.58**
Mean potential residential built area (m^2)				4.90
Potential residential built area (m^2)	*Structure 1*	*3.22*	*Structure 4*	*4.80*
	Structure 2	*6.80*	*Structure 5*	*2.59*
	Structure 3	*3.68*	*Structure 10*	*8.32*
Total built area estimate (m^2)				547.24
			Assessable area (m^2)	*61.49*
			Assessable built area (m^2)	*33.65*
			Assessable built area as a proportion of assessable area	*0.5472*
			Estimated total site extent (m^2)	*1000*
Residential built area as a proportion of assessable built area				0.8741
			Potential residential built area (m^2)	*29.41*
Total potential residential built area (m^2)				478.32
Method 3: Total potential dwelling number				**97.58**
Potential residential built area as a proportion of assessable area				0.4783
Total number of contemporaneous dwellings (75%)				73.18
Total population estimate based on nuclear family size:	**Minimum**	**3**		**219.55**
	Average	**5.5**		**402.50**
	Maximum	**8**		**585.46**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)					**303.08**
Potential residential floor area (m^2)					18.64
Potential residential floor area (m^2)	*Structure 1*	*1.89*	*Structure 4*		*3.13*
	Structure 2	*3.93*	*Structure 5*		*1.42*
	Structure 3	*2.54*	*Structure 10*		*5.72*
Assessable area (m^2)					61.49
Estimated total site extent (m^2)					1000
Assessable area (proportion)					0.0615
Method 2: Total potential residential floor area (m^2)					**303.08**
Total built area estimate (m^2)					547.24
				Assessable area (m^2)	*61.49*
				Assessable built area (m^2)	*33.65*
				Assessable built area as a proportion of assessable area	*0.5472*
				Estimated total site extent (m^2)	*1000*
Potential residential floor area as a proportion of assessable built area					0.5538
				Potential residential floor area (m^2)	*18.64*
Method 3: Total potential residential floor area (m^2)					**303.08**
Potential residential floor area as a proportion of assessable area					0.3031
Total contemporaneous residential floor area (m^2) (75%)					227.31
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**			**128.42**
	Average	**3.3**			**68.88**
	Maximum	**5**			**45.46**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	227.31	0.3944 x 227.31	=	89.65	0.2477 x 227.31	=	56.30	0.1903 x 227.31	=	43.26
P	=	?	89.65 - 0.375	=	89.28	56.3 + 0.0339	=	56.34	43.26 + 0.3976	=	43.65
			P	**=**	**89.28**	**P**	**=**	**56.34**	**P**	**=**	**43.65**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	4.83	0.3944 x 4.83	=	1.90	0.2477 x 4.83	=	1.20	0.1903 x 4.83	=	0.92
P	=	?	1.9 - 0.375	=	1.53	1.2 + 0.0339	=	1.23	0.92 + 0.3976	=	1.28
			P	**=**	**1.53**	**P**	**=**	**1.23**	**P**	**=**	**1.28**
						Total number of contemporaneous dwellings					*73.18*
		Total population			**111.96**			**90.03**			**93.56**
Mean total population					**100.62**			**73.19**			**68.61**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (100.62)	*Moderate (73.19)*	*Maximum (68.61)*		*None (100.62)*	*Moderate (73.19)*	*Maximum (68.61)*
Total built floor area (m^2)	1053.46	805.77	763.10	345.75			
Built floor area per person (m^2)	10.47	11.01	11.12		3.44	4.72	5.04
RADC (m^2 per person)	9.18	9.65	9.75		2.26	3.11	3.31
Initial growth index	7.12	9.31	9.83				

Data required		
SPF population estimate (P) based on amount of storage:	None	100.62
	Moderate	73.19
	Maximum	68.61
Residential floor area as a proportion of built floor area (%)		87.66
Total built floor area (m^2) (A)		*345.75*
Built floor area in assessable area (m^2)		*21.26*
Proportion of site assessable (%)		*6.15*
Total residential floor area (m^2) (RADC method)		*303.08*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	3.44
	Moderate	4.72
	Maximum	5.04
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.26
	Moderate	3.11
	Maximum	3.31
Total contemporaneous residential floor area (m^2) (RADC method)		227.31

Amount of storage:	**$A = a \times P^b$**					
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 100.62^{0.84195}$**		
	P	=	100.62	$100.62^{0.84195}$	=	48.55
	a	=	21.7	21.7 x 48.55	=	1053.46
	b	=	0.84195	**A**	**=**	**1053.46**
	Built floor area per person (m^2)					**10.47**
	RADC (m^2 per person)					**9.18**
	Residential floor area as a proportion of built floor area					*87.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	345.75	**$345.75 = a \times 100.62^{0.84195}$**		
	P	=	100.62	$100.62^{0.84195}$	=	48.55
	a	=	?	345.75/48.55	=	7.12
	b	=	0.84195	***a***	**=**	**7.12**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 73.19^{0.84195}$**		
	P	=	73.19	$73.19^{0.84195}$	=	37.13
	a	=	21.7	21.7 x 37.13	=	805.77
	b	=	0.84195	**A**	**=**	**805.77**
	Built floor area per person (m^2)					**11.01**
	RADC (m^2 per person)					**9.65**
	Residential floor area as a proportion of built floor area					*87.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	345.75	**$345.75 = a \times 73.19^{0.84195}$**		
	P	=	73.19	$73.19^{0.84195}$	=	37.13
	a	=	?	345.75/37.13	=	9.31
	b	=	0.84195	***a***	**=**	**9.31**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 68.61^{0.84195}$**		
	P	=	68.61	$68.61^{0.84195}$	=	35.17
	a	=	21.7	21.7 x 35.17	=	763.10
	b	=	0.84195	**A**	**=**	**763.10**
	Built floor area per person (m^2)					**11.12**
	RADC (m^2 per person)					**9.75**
	Residential floor area as a proportion of built floor area					*87.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	345.75	**$345.75 = a \times 68.61^{0.84195}$**		
	P	=	68.61	$68.61^{0.84195}$	=	35.17
	a	=	?	345.75/35.17	=	9.83
	b	=	0.84195	***a***	**=**	**9.83**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		1000
SPF population estimate (P) based on amount of storage:	None	100.62
	Moderate	73.19
	Maximum	68.61

					$A = a \times P^b$			
Amount of storage:	*None*	**Open settlements**			**$1000 = a \times 100.62^2$**			
		A	=	1000				
		P	=	100.62	100.62^2		=	10124.18
		a	=	?	1000/10124.18		=	0.10
		b	=	2	***a***		**=**	**0.10**
		Village settlements			**$1000 = a \times 100.62^1$**			
		A	=	1000				
		P	=	100.62	100.62^1		=	100.62
		a	=	?	1000/100.62		=	9.9
		b	=	1	***a***		**=**	**9.9**
		Urban settlements			**$1000 = a \times 100.62^{0.6667}$**			
		A	=	1000				
		P	=	100.62	$100.62^{0.6667}$		=	21.64
		a	=	?	1000/21.64		=	46.22
		b	=	0.6667	***a***		**=**	**46.22**
	Moderate	**Open settlements**			**$1000 = a \times 73.19^2$**			
		A	=	1000				
		P	=	73.19	73.19^2		=	5356.14
		a	=	?	1000/5356.14		=	0.19
		b	=	2	***a***		**=**	**0.19**
		Village settlements			**$1000 = a \times 73.19^1$**			
		A	=	1000				
		P	=	73.19	73.19^1		=	73.19
		a	=	?	1000/73.19		=	13.7
		b	=	1	***a***		**=**	**13.7**
		Urban settlements			**$1000 = a \times 73.19^{0.6667}$**			
		A	=	1000				
		P	=	73.19	$73.19^{0.6667}$		=	17.50
		a	=	?	1000/17.5		=	57.15
		b	=	0.6667	***a***		**=**	**57.15**
	Maximum	**Open settlements**			**$1000 = a \times 68.61^2$**			
		A	=	1000				
		P	=	68.61	68.61^2		=	4706.76
		a	=	?	1000/4706.76		=	0.21
		b	=	2	***a***		**=**	**0.21**
		Village settlements			**$1000 = a \times 68.61^1$**			
		A	=	1000				
		P	=	68.61	68.61^1		=	68.61
		a	=	?	1000/68.61		=	14.6
		b	=	1	***a***		**=**	**14.6**
		Urban settlements			**$1000 = a \times 68.61^{0.6667}$**			
		A	=	1000				
		P	=	68.61	$68.61^{0.6667}$		=	16.76
		a	=	?	1000/16.76		=	59.66
		b	=	0.6667	***a***		**=**	**59.66**

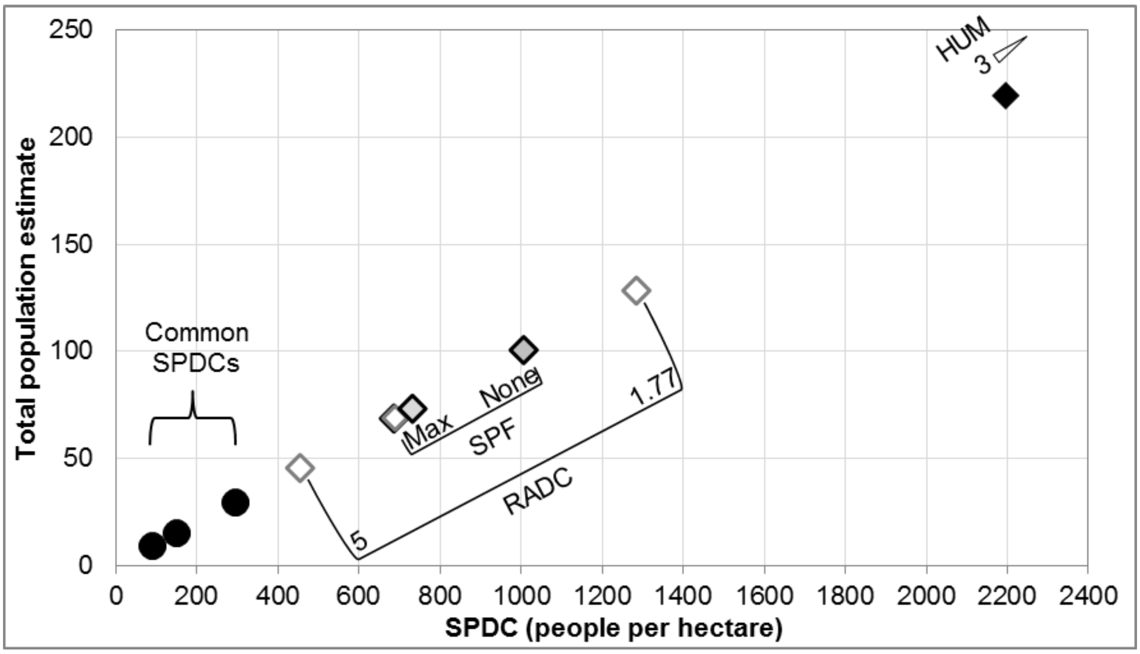
Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (100.62)	*Moderate (73.19)*	*Maximum (68.61)*
Open	0.10	0.19	0.21
Village	9.94	13.66	14.58
Urban	46.22	57.15	59.66

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	0.1
Proportion of site assessable (%)	6.15
Number of contemporaneous dwellings in the assessable area	4.50
Dwellings in assessable area	*6*
Contemporaneity value (%)	*75*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum 90	*Average 150*	*Maximum 294*
Total population	9	15	29.4
Population in the assessable area	*0.55*	*0.92*	*1.81*
People per dwelling in the assessable area	*0.12*	*0.20*	*0.40*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	219.55	-	-	2195.48	-	-
RADC	45.46	68.88	128.42	454.62	688.82	1284.23
SPF	68.61	73.19	100.62	686.06	731.86	1006.19



Shkārat Msaied

Assessable area (m^2)	Assessable area			717.34
	Unassessable area			37.43
	Total			**679.91**
Potential residential built area (m^2)	Unit A(*)	20.54	Unit K*	33.60
	Unit B(*)	17.67	Unit L*	21.67
	Unit C*	23.01	Unit R*	18.48
	Unit D*	22.35	Unit T*	26.44
	Unit E*	26.30	Unit X	3.66
	Unit H*	45.80	Unit Y	18.97
	Unit J*	33.65		
	Total			**312.15**
	Mean			24.01
	SD (±)			10.01
	*Mean residential built area: complete dwellings			26.32
	((*) marginally incomplete building)			
Potential non-residential built area (m^2)	Unit F			44.73
	Unit U			13.19
	Enclosure b			7.69
	Enclosure g			17.48
	Total			**83.08**
Built area (m^2)	Potential residential built area			312.15
	Potential non-residential built area			83.08
	Total			**395.23**

Potential residential floor area (m^2)	Unit A*	9.44	Unit K*	17.24
	Unit B*	8.59	Unit L*	9.30
	Unit C*	12.94	Unit R*	8.65
	Unit D*	10.30	Unit T*	16.07
	Unit E*	13.24	Unit X	0.68
	Unit H*	25.81	Unit Y	10.14
	Unit J*	16.44		
	Total			**158.85**
	*Mean residential floor area: complete dwellings			13.46
Built floor area (m^2)	Unit A	9.44	Unit L	9.30
	Unit B	8.59	Unit R	8.65
	Unit C	12.94	Unit T	16.07
	Unit D	10.30	Unit U	4.40
	Unit E	13.24	Unit X	0.68
	Unit F	24.36	Unit Y	10.14
	Unit H	25.81	Enclosure b	4.52
	Unit J	16.44	Enclosure g	8.24
	Unit K	17.24		
	Total			**200.37**

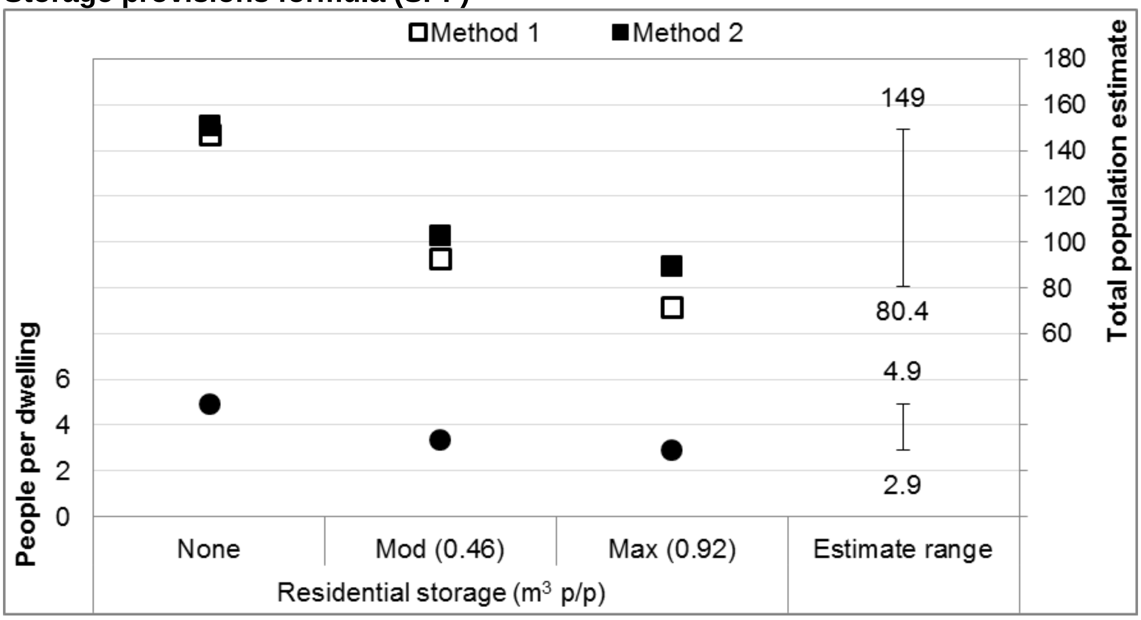
Housing unit method (HUM)

Method 1: Total potential dwelling number					**38.24**
Number of potential dwellings in the assessable area					13
Assessable area (m^2)					679.91
Estimated total site extent (m^2)					2000
Assessable area (proportion)					0.3400
Method 2: Total potential dwelling number					**38.24**
Mean potential residential built area (m^2)					24.01
Potential residential built area (m^2)	*Unit A*	*20.54*	*Unit K*		*33.60*
	Unit B	*17.67*	*Unit L*		*21.67*
	Unit C	*23.01*	*Unit R*		*18.48*
	Unit D	*22.35*	*Unit T*		*26.44*
	Unit E	*26.30*	*Unit X*		*3.66*
	Unit H	*45.80*	*Unit Y*		*18.97*
	Unit J	*33.65*			
Total built area estimate (m^2)					1162.60
				Assessable area (m^2)	*679.91*
				Assessable built area (m^2)	*395.23*
				Assessable built area as a proportion of assessable area	*0.5813*
				Estimated total site extent (m^2)	*2000*
Residential built area as a proportion of assessable built area					0.7898
				Potential residential built area (m^2)	*312.15*
Total potential residential built area (m^2)					918.22
Method 3: Total potential dwelling number					**38.24**
Potential residential built area as a proportion of assessable area					0.4591
Total number of contemporaneous dwellings (80%)					30.59
Total population estimate based on nuclear family size:			**Minimum**	**3**	**91.78**
			Average	**5.5**	**168.26**
			Maximum	**8**	**244.74**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)					**467.27**
Potential residential floor area (m^2)					158.85
Potential residential floor area (m^2)	*Unit A*	*9.44*	*Unit K*		*17.24*
	Unit B	*8.59*	*Unit L*		*9.30*
	Unit C	*12.94*	*Unit R*		*8.65*
	Unit D	*10.30*	*Unit T*		*16.07*
	Unit E	*13.24*	*Unit X*		*0.68*
	Unit H	*25.81*	*Unit Y*		*10.14*
	Unit J	*16.44*			
Assessable area (m^2)					679.91
Estimated total site extent (m^2)					2000
Assessable area (proportion)					0.3400
Method 2: Total potential residential floor area (m^2)					**467.27**
Total built area estimate (m^2)					1162.60
				Assessable area (m^2)	*679.91*
				Assessable built area (m^2)	*395.23*
				Assessable built area as a proportion of assessable area	*0.5813*
				Estimated total site extent (m^2)	*2000*
Potential residential floor area as a proportion of assessable built area					0.4019
				Potential residential floor area (m^2)	*158.85*
Method 3: Total potential residential floor area (m^2)					**467.27**
Potential residential floor area as a proportion of assessable area					0.2336
Total contemporaneous residential floor area (m^2) (80%)					373.81
Total population estimate based on RADC (m^2):		**Minimum**	**1.77**		**211.19**
		Average	**3.3**		**113.28**
		Maximum	**5**		**74.76**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	373.81	0.3944 x 373.81	=	147.43	0.2477 x 373.81	=	92.59	0.1903 x 373.81	=	71.14
P	=	?	147.43 - 0.375	=	147.06	92.59 + 0.0339	=	92.63	71.14 + 0.3976	=	71.53
			P	**=**	**147.06**	**P**	**=**	**92.63**	**P**	**=**	**71.53**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	13.46	0.3944 x 13.46	=	5.31	0.2477 x 13.46	=	3.33	0.1903 x 13.46	=	2.56
P	=	?	5.31 - 0.375	=	4.93	3.33 + 0.0339	=	3.37	2.56 + 0.3976	=	2.92
			P	**=**	**4.93**	**P**	**=**	**3.37**	**P**	**=**	**2.92**
						Total number of contemporaneous dwellings					*30.59*
		Total population			**150.92**			**103.03**			**89.35**
Mean total population					**148.99**			**97.83**			**80.44**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**			**Archaeological evidence**			
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (148.99)	*Moderate (97.83)*	*Maximum (80.44)*		*None (148.99)*	*Moderate (97.83)*	*Maximum (80.44)*
Total built floor area (m^2)	1466.03	1028.78	872.51	589.32			
Built floor area per person (m^2)	9.84	10.52	10.85		3.96	6.02	7.33
RADC (m^2 per person)	7.80	8.34	8.60		2.51	3.82	4.65
Initial growth index	8.72	12.43	14.66				

Data required		
SPF population estimate (P) based on amount of storage:	None	148.99
	Moderate	97.83
	Maximum	80.44
Residential floor area as a proportion of built floor area (%)		79.29
Total built floor area (m^2) (A)		*589.32*
Built floor area in assessable area (m^2)		*200.37*
Proportion of site assessable (%)		*34.00*
Total residential floor area (m^2) (RADC method)		*467.27*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	3.96
	Moderate	6.02
	Maximum	7.33
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.51
	Moderate	3.82
	Maximum	4.65
Total contemporaneous residential floor area (m^2) (RADC method)		373.81

$A = a \times P^b$

Amount of storage:							
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 148.99^{0.84195}$**			
	P	=	148.99	$148.99^{0.84195}$		=	67.56
	a	=	21.7	21.7 x 67.56		=	1466.03
	b	=	0.84195	**A**		**=**	**1466.03**
	Built floor area per person (m^2)						**9.84**
	RADC (m^2 per person)						**7.80**
	Residential floor area as a proportion of built floor area						*79.29*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	589.32	**$589.32 = a \times 148.99^{0.84195}$**			
	P	=	148.99	$148.99^{0.84195}$		=	67.56
	a	=	?	589.32/67.56		=	8.72
	b	=	0.84195	***a***		**=**	**8.72**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 97.83^{0.84195}$**			
	P	=	97.83	$97.83^{0.84195}$		=	47.41
	a	=	21.7	21.7 x 47.41		=	1028.78
	b	=	0.84195	**A**		**=**	**1028.78**
	Built floor area per person (m^2)						**10.52**
	RADC (m^2 per person)						**8.34**
	Residential floor area as a proportion of built floor area						*79.29*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	589.32	**$589.32 = a \times 97.83^{0.84195}$**			
	P	=	97.83	$97.83^{0.84195}$		=	47.41
	a	=	?	589.32/47.41		=	12.43
	b	=	0.84195	***a***		**=**	**12.43**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 80.44^{0.84195}$**			
	P	=	80.44	$80.44^{0.84195}$		=	40.21
	a	=	21.7	21.7 x 40.21		=	872.51
	b	=	0.84195	**A**		**=**	**872.51**
	Built floor area per person (m^2)						**10.85**
	RADC (m^2 per person)						**8.60**
	Residential floor area as a proportion of built floor area						*79.29*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	589.32	**$589.32 = a \times 80.44^{0.84195}$**			
	P	=	80.44	$80.44^{0.84195}$		=	40.21
	a	=	?	589.32/40.21		=	14.66
	b	=	0.84195	***a***		**=**	**14.66**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		2000
SPF population estimate (P) based on amount of storage:	None	148.99
	Moderate	97.83
	Maximum	80.44

$A = a \times P^b$

Amount of storage:							
None	**Open settlements**			**$2000 = a \times 148.99^2$**			
	A	=	2000				
	P	=	148.99	148.99^2		=	22197.31
	a	=	?	2000/22197.31		=	0.09
	b	=	2	***a***		**=**	**0.09**
	Village settlements			**$2000 = a \times 148.99^1$**			
	A	=	2000				
	P	=	148.99	148.99^1		=	148.99
	a	=	?	2000/148.99		=	13.4
	b	=	1	***a***		**=**	**13.4**
	Urban settlements			**$2000 = a \times 148.99^{0.6667}$**			
	A	=	2000				
	P	=	148.99	$148.99^{0.6667}$		=	28.11
	a	=	?	2000/28.11		=	71.15
	b	=	0.6667	***a***		**=**	**71.15**
Moderate	**Open settlements**			**$2000 = a \times 97.83^2$**			
	A	=	2000				
	P	=	97.83	97.83^2		=	9569.92
	a	=	?	2000/9569.92		=	0.21
	b	=	2	***a***		**=**	**0.21**
	Village settlements			**$2000 = a \times 97.83^1$**			
	A	=	2000				
	P	=	97.83	97.83^1		=	97.83
	a	=	?	2000/97.83		=	20.4
	b	=	1	***a***		**=**	**20.4**
	Urban settlements			**$2000 = a \times 97.83^{0.6667}$**			
	A	=	2000				
	P	=	97.83	$97.83^{0.6667}$		=	21.23
	a	=	?	2000/21.23		=	94.19
	b	=	0.6667	***a***		**=**	**94.19**
Maximum	**Open settlements**			**$2000 = a \times 80.44^2$**			
	A	=	2000				
	P	=	80.44	80.44^2		=	6470.51
	a	=	?	2000/6470.51		=	0.31
	b	=	2	***a***		**=**	**0.31**
	Village settlements			**$2000 = a \times 80.44^1$**			
	A	=	2000				
	P	=	80.44	80.44^1		=	80.44
	a	=	?	2000/80.44		=	24.9
	b	=	1	***a***		**=**	**24.9**
	Urban settlements			**$2000 = a \times 80.44^{0.6667}$**			
	A	=	2000				
	P	=	80.44	$80.44^{0.6667}$		=	18.64
	a	=	?	2000/18.64		=	107.31
	b	=	0.6667	***a***		**=**	**107.31**

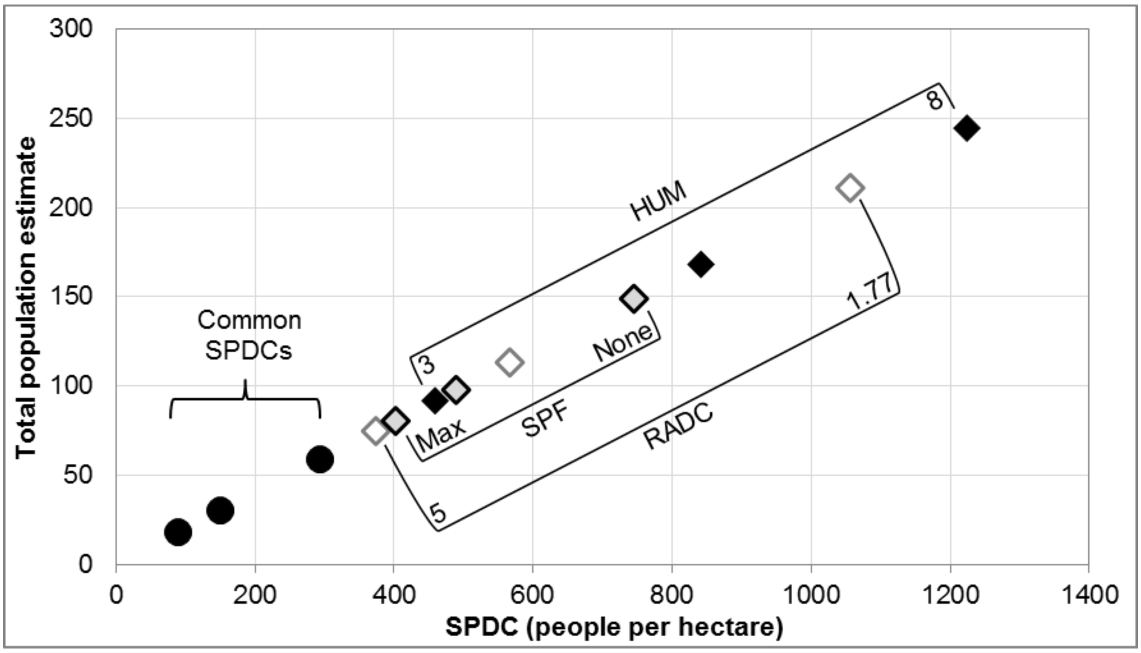
Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (148.99)	*Moderate (97.83)*	*Maximum (80.44)*
Open	0.09	0.21	0.31
Village	13.42	20.44	24.86
Urban	71.15	94.19	107.31

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	0.2
Proportion of site assessable (%)	34.00
Number of contemporaneous dwellings in the assessable area	10.40
Dwellings in assessable area	*13*
Contemporaneity value (%)	*80*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	18	30	58.8
Population in the assessable area	*6.12*	*10.20*	*19.99*
People per dwelling in the assessable area	*0.59*	*0.98*	*1.92*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	91.78	168.26	244.74	458.88	841.29	1223.69
RADC	74.76	113.28	211.19	373.81	566.39	1055.97
SPF	80.44	97.83	148.99	402.20	489.13	744.94



Ghwair I

Assessable area (m^2)	Assessable area				588.7
	Unassessable area				147.95
	Total				**440.75**
Potential residential built area (m^2)	Ground floor	Unit I: room 5			23.28
		Unit II: room 17			20.05
	Upper storey	Unit III	24.78	Unit V	20.05
		Unit IV	31.68	Unit VI	24.44
	Total				**144.27**
	Mean				24.04
	SD (±)				4.28
	Mean residential built area (all complete)				24.04
Potential non-residential built area (m^2)	Ground floor	Unit I: rooms 1-4	12.60	Room 6	5.66
		Unit II: rooms 14-16	7.46	Room 8	5.74
		Unit III	24.78	Rooms 9-12	14.76
		Unit IV	31.68	Room 50	16.48
		Unit V	28.49	Communal staircase	11.29
		Unit VI	33.70		
		Water management walls and corridors (?)			45.69
	Total				**238.34**
Built area (m^2)	Potential residential built area (ground floor)				43.33
	Potential non-residential built area				238.34
	Total				**281.67**

				Adjusted[a]			Adjusted
Potential residential floor area (m^2)	Ground floor	Unit I: room 5				13.57	
		Unit II: room 17				13.95	
	Upper storey	Unit III	18.83	15.54	Unit V	15.68	12.94
		Unit IV	21.65	17.86	Unit VI	20.60	17.00
	Total					**76.77**	**90.85**
	Mean residential floor area (all complete)					19.19	15.14
Built floor area (m^2)	Ground floor	Unit I	18.80		Room 11	1.22	
		Unit II	16.30		Room 10	0.63	
		Unit III	10.03		Room 12	1.58	
		Unit IV	14.56		Room 49	2.60	
		Unit V	6.90		Room 50	11.98	
		Unit VI	11.31		Room 51	0.67	
		Room 6	3.27		Room 52	0.45	
		Room 8	3.09		Room 53	3.02	
		Room 9	0.82				
	Upper storey	Unit III	18.83	15.54	Unit V	15.68	12.94
		Unit IV	21.65	17.86	Unit VI	20.60	17.00
	Total					**184.01**	**170.57**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

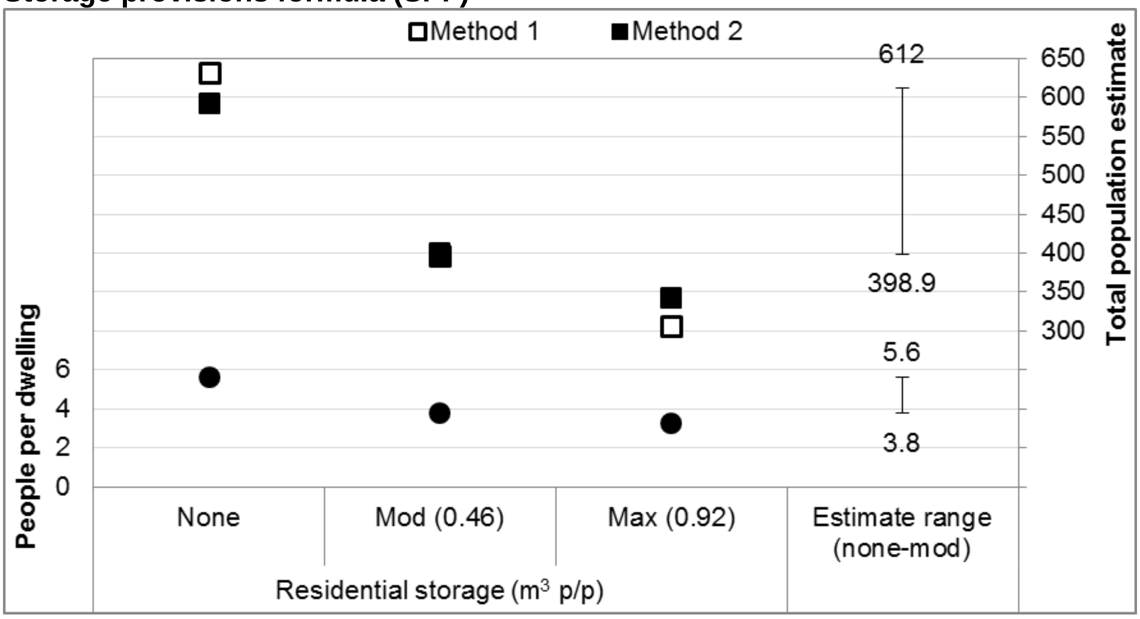
Housing unit method (HUM)

Method 1: Total potential dwelling number					**136.13**
Number of potential dwellings in the assessable area					6
Assessable area (m^2)					440.75
Estimated total site extent (m^2)					10000
Assessable area (proportion)					0.0441
Method 2: Total potential dwelling number					**136.13**
Mean potential residential built area (m^2)					24.04
Potential residential built area (m^2)	*Unit I*	*23.28*		*Unit IV*	*31.68*
	Unit II	*20.05*		*Unit V*	*20.05*
	Unit III	*24.78*		*Unit VI*	*24.44*
Total built area estimate (m^2)					6390.70
				Assessable area (m^2)	*440.75*
				Assessable built area (m^2)	*281.67*
				Assessable built area as a proportion of assessable area	*0.6391*
				Estimated total site extent (m^2)	*10000*
Residential built area as a proportion of assessable built area					0.5122
				Potential residential built area (m^2)	*144.27*
Total potential residential built area (m^2)					3273.20
Method 3: Total potential dwelling number					**136.13**
Potential residential built area as a proportion of assessable area					0.3273
Total number of contemporaneous dwellings (77.78%)					105.88
Total population estimate based on nuclear family size:			**Minimum**	**3**	**317.65**
			Average	**5.5**	**582.36**
			Maximum	**8**	**847.07**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)				**2061.31**
Potential residential floor area (m^2)				90.85
Potential residential floor area (m^2)	*Unit I*	*13.57*	*Unit IV*	*17.86*
	Unit II	*13.95*	*Unit V*	*12.94*
	Unit III	*15.54*	*Unit VI*	*17.00*
Assessable area (m^2)				440.75
Estimated total site extent (m^2)				10000
Assessable area (proportion)				0.0441
Method 2: Total potential residential floor area (m^2)				**2061.31**
Total built area estimate (m^2)				6390.70
			Assessable area (m^2)	*440.75*
			Assessable built area (m^2)	*281.67*
			Assessable built area as a proportion of assessable area	*0.6391*
			Estimated total site extent (m^2)	*10000*
Potential residential floor area as a proportion of assessable built area				0.3225
			Potential residential floor area (m^2)	*90.85*
Method 3: Total potential residential floor area (m^2)				**2061.31**
Potential residential floor area as a proportion of assessable area				0.2061
Total contemporaneous residential floor area (m^2) (77.78%)				1603.29
Total population estimate based on RADC (m^2):		**Minimum**	**1.77**	**905.81**
		Average	**3.3**	**485.84**
		Maximum	**5**	**320.66**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	1603.29	0.3944 x 1603.29	=	632.34	0.2477 x 1603.29	=	397.13	0.1903 x 1603.29	=	305.11
P	=	?	632.34 - 0.375	=	631.96	397.13 + 0.0339	=	397.17	305.11 + 0.3976	=	305.50
			P	**=**	**631.96**	**P**	**=**	**397.17**	**P**	**=**	**305.50**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	15.14	0.3944 x 15.14	=	5.97	0.2477 x 15.14	=	3.75	0.1903 x 15.14	=	2.88
P	=	?	5.97 - 0.375	=	5.60	3.75 + 0.0339	=	3.78	2.88 + 0.3976	=	3.24
			P	**=**	**5.60**	**P**	**=**	**3.78**	**P**	**=**	**3.24**
						Total number of contemporaneous dwellings					*105.88*
		Total population			**592.54**			**400.67**			**343.11**
Mean total population					**612.25**			**398.9**			**324.3**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (612.25)	*Moderate (398.92)*	*Maximum (324.31)*		*None (612.25)*	*Moderate (398.92)*	*Maximum (324.31)*
Total built floor area (m^2)	4818.55	3359.50	2822.01	3869.99			
Built floor area per person (m^2)	7.87	8.42	8.70		6.32	9.70	11.93
RADC (m^2 per person)	4.19	4.49	4.63		2.62	4.02	4.94
Initial growth index	17.43	25.00	29.76				

Data required		
SPF population estimate (P) based on amount of storage:	None	612.25
	Moderate	398.92
	Maximum	324.31
Residential floor area as a proportion of built floor area (%)		53.26
Total built floor area (m^2) (A)		*3869.99*
Built floor area in assessable area (m^2)		*170.57*
Proportion of site assessable (%)		*4.41*
Total residential floor area (m^2) (RADC method)		*2061.31*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	6.32
	Moderate	9.70
	Maximum	11.93
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.62
	Moderate	4.02
	Maximum	4.94
Total contemporaneous residential floor area (m^2) (RADC method)		1603.29

Amount of storage:		**$A = a \times P^b$**					
	None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 612.25^{0.84195}$**		
		P	=	612.25	$612.25^{0.84195}$	=	222.05
		a	=	21.7	21.7 x 222.05	=	4818.55
		b	=	0.84195	**A**	**=**	**4818.55**
		Built floor area per person (m^2)					**7.87**
		RADC (m^2 per person)					**4.19**
					Residential floor area as a proportion of built floor area		*53.26*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	3869.99	**$3869.99 = a \times 612.25^{0.84195}$**		
		P	=	612.25	$612.25^{0.84195}$	=	222.05
		a	=	?	3869.99/222.05	=	17.43
		b	=	0.84195	***a***	**=**	**17.43**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 398.92^{0.84195}$**		
		P	=	398.92	$398.92^{0.84195}$	=	154.82
		a	=	21.7	21.7 x 154.82	=	3359.50
		b	=	0.84195	**A**	**=**	**3359.50**
		Built floor area per person (m^2)					**8.42**
		RADC (m^2 per person)					**4.49**
					Residential floor area as a proportion of built floor area		*53.26*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	3869.99	**$3869.99 = a \times 398.92^{0.84195}$**		
		P	=	398.92	$398.92^{0.84195}$	=	154.82
		a	=	?	3869.99/154.82	=	25.00
		b	=	0.84195	***a***	**=**	**25.00**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 324.31^{0.84195}$**		
		P	=	324.31	$324.31^{0.84195}$	=	130.05
		a	=	21.7	21.7 x 130.05	=	2822.01
		b	=	0.84195	**A**	**=**	**2822.01**
		Built floor area per person (m^2)					**8.70**
		RADC (m^2 per person)					**4.63**
					Residential floor area as a proportion of built floor area		*53.26*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	3869.99	**$3869.99 = a \times 324.31^{0.84195}$**		
		P	=	324.31	$324.31^{0.84195}$	=	130.05
		a	=	?	3869.99/130.05	=	29.76
		b	=	0.84195	***a***	**=**	**29.76**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		13250
SPF population estimate (P) based on amount of storage:	None	612.25
	Moderate	398.92
	Maximum	324.31

$A = a \times P^b$

Amount of storage:							
	None	**Open settlements**			**$13250 = a \times 612.25^2$**		
		A	=	13250			
		P	=	612.25	612.25^2	=	374853.93
		a	=	?	13250/374853.93	=	0.04
		b	=	2	***a***	**=**	**0.04**
		Village settlements			**$13250 = a \times 612.25^1$**		
		A	=	13250			
		P	=	612.25	612.25^1	=	612.25
		a	=	?	13250/612.25	=	21.6
		b	=	1	***a***	**=**	**21.6**
		Urban settlements			**$13250 = a \times 612.25^{0.6667}$**		
		A	=	13250			
		P	=	612.25	$612.25^{0.6667}$	=	72.12
		a	=	?	13250/72.12	=	183.73
		b	=	0.6667	***a***	**=**	**183.73**
	Moderate	**Open settlements**			**$13250 = a \times 398.92^2$**		
		A	=	13250			
		P	=	398.92	398.92^2	=	159136.43
		a	=	?	13250/159136.43	=	0.08
		b	=	2	***a***	**=**	**0.08**
		Village settlements			**$13250 = a \times 398.92^1$**		
		A	=	13250			
		P	=	398.92	398.92^1	=	398.92
		a	=	?	13250/398.92	=	33.2
		b	=	1	***a***	**=**	**33.2**
		Urban settlements			**$13250 = a \times 398.92^{0.6667}$**		
		A	=	13250			
		P	=	398.92	$398.92^{0.6667}$	=	54.20
		a	=	?	13250/54.2	=	244.46
		b	=	0.6667	***a***	**=**	**244.46**
	Maximum	**Open settlements**			**$13250 = a \times 324.31^2$**		
		A	=	13250			
		P	=	324.31	324.31^2	=	105174.15
		a	=	?	13250/105174.15	=	0.13
		b	=	2	***a***	**=**	**0.13**
		Village settlements			**$13250 = a \times 324.31^1$**		
		A	=	13250			
		P	=	324.31	324.31^1	=	324.31
		a	=	?	13250/324.31	=	40.9
		b	=	1	***a***	**=**	**40.9**
		Urban settlements			**$13250 = a \times 324.31^{0.6667}$**		
		A	=	13250			
		P	=	324.31	$324.31^{0.6667}$	=	47.21
		a	=	?	13250/47.21	=	280.65
		b	=	0.6667	***a***	**=**	**280.65**

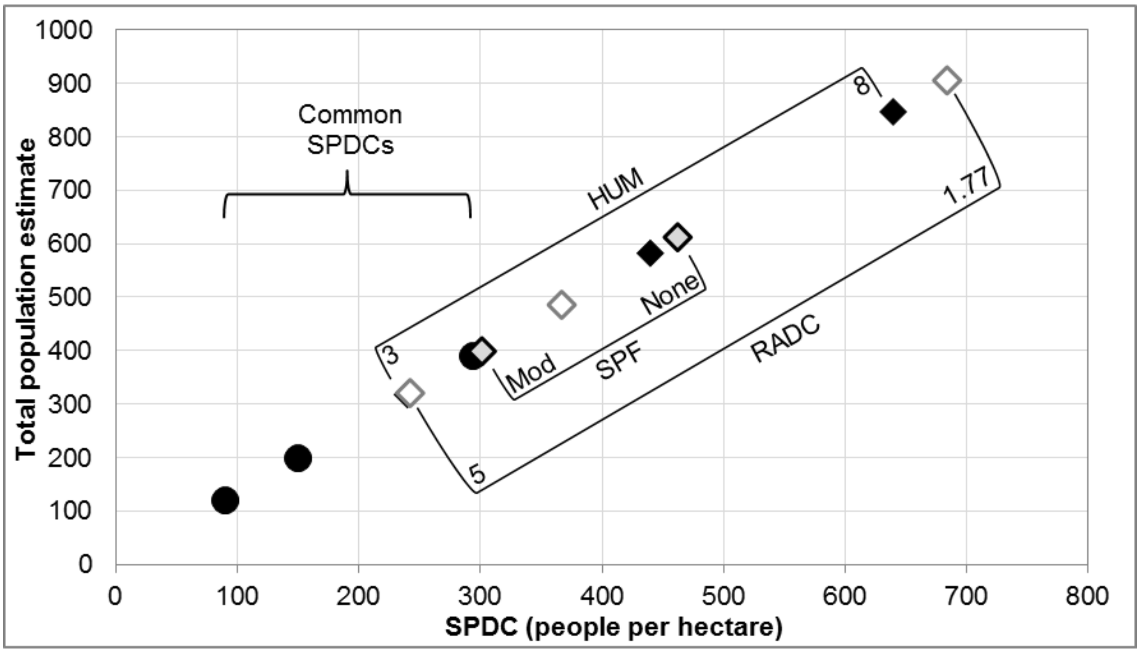
Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (612.25)	*Moderate (398.92)*	*Maximum (324.31)*
Open	0.04	0.08	0.13
Village	21.64	33.21	40.86
Urban	183.73	244.46	280.65

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	1.325
Proportion of site assessable (%)	4.41
Number of contemporaneous dwellings in the assessable area	4.67
Dwellings in assessable area	*6*
Contemporaneity value (%)	*77.78*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	119.25	198.75	389.55
Population in the assessable area	*5.26*	*8.76*	*17.18*
People per dwelling in the assessable area	*1.13*	*1.88*	*3.68*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	317.65	582.36	847.07	239.74	439.51	639.29
RADC	320.66	485.84	905.81	242.01	366.68	683.63
SPF	-	398.92	612.25	-	301.07	462.08



Wadi Hamarash I

Category	Level	Description	Value	Description	Value
Assessable area (m^2)		Assessable area		Area 1	249.35
				Area 2	206.34
				Area 3	171.97
				Area 4	398.33
				Area 5	536.19
		Unassessable area			312.7
		Total			**1249.48**
Potential residential built area (m^2)	Ground floor	*Area 1*		*Area 3*	
		Unit I: locus 16(*)	22.55	Unit I: loci 4/5	16.97
		Unit II: locus 20*	13.53	Unit II: locus 13	4.50
		Unit III: locus 10*	24.08		
		Unit IV: locus 1*	17.32		
		Area 2		*Area 5*	
		Unit I: locus 23(*)	14.49	Unit I: loci 11/12*	35.82
		Unit III: locus 1*	21.19	Unit II: locus 19	14.10
		Unit IV: locus 7	7.37	Unit IV: locus 13*	19.13
	Upper storey	Area 1: Unit V: loci 2/18*			23.07
		Area 2: Unit II: locus 20*			7.17
		Area 3: Unit III: loci 11/12*			12.21
		Area 5: Unit III: loci 2/5/7*			21.15
		Total			**274.65**
		Mean			17.17
		SD (±)			7.77
		*Mean residential built area: complete dwellings			21.01
		((*) marginally incomplete building)			
Potential non-residential built area (m^2)	Ground floor	Area 1			113.91
		Area 2			131.46
		Area 3			54.91
		Area 4			132.47
		Area 5			145.37
		Total			**578.12**

Category	Level	Description	Value	Description	Value	Adjusted[a]
Built area (m^2)		Potential residential built area (ground floor)				211.05
		Potential non-residential built area				578.12
		Total				**789.16**
Potential residential floor area (m^2)	Ground floor	*Area 1*		*Area 3*		
		Unit I: locus 16*	15.17	Unit I: loci 4/5	9.25	
		Unit II: locus 20*	8.45	Unit II: locus 13	3.02	
		Unit III: locus 10*	17.51			
		Unit IV: locus 1*	12.61			
		Area 2		*Area 5*		
		Unit I: locus 23*	11.58	Unit I: loci 11/12*	22.79	
		Unit III: locus 1*	11.95	Unit II: locus 19	10.98	
		Unit IV: locus 7	4.71	Unit IV: locus 13*	10.70	
	Upper storey	Area 1: Unit V: loci 2/18*			19.39	15.99
		Area 2: Unit II: locus 20*			5.81	4.80
		Area 3: Unit III: loci 11/12*			9.35	7.72
		Area 5: Unit III: loci 2/5/7*			17.32	14.29
		Total			**190.60**	**181.52**
		*Mean residential floor area: complete dwellings			12.97	12.22
Built floor area (m^2)	Ground floor	Area 1			107.04	
		Area 2			107.97	
		Area 3			39.54	
		Area 4: Communal building			92.65	
		Area 5			66.87	
	Upper storey	Area 1: Unit V: loci 2/18			19.39	15.99
		Area 2: Unit II: locus 20			5.81	4.80
		Area 3: Unit III: loci 11/12			9.35	7.72
		Area 5: Unit III: loci 2/5/7			17.32	14.29
		Total			**465.93**	**456.85**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

Housing unit method (HUM)

Method 1: Total potential dwelling number				**64.03**
Number of potential dwellings in the assessable area				16
Assessable area (m^2)				1249.48
Estimated total site extent (m^2)				5000
Assessable area (proportion)				0.2499
Method 2: Total potential dwelling number				**64.03**
Mean potential residential built area (m^2)				17.17
Potential residential built area (m^2)	*Area 1*		*Area 3*	
	Unit I: locus 16	*22.55*	*Unit I: loci 4/5*	*16.97*
	Unit II: locus 20	*13.53*	*Unit II: locus 13*	*4.50*
	Unit III: locus 10	*24.08*	*Unit III: loci 11/12*	*12.21*
	Unit IV: locus 1	*17.32*		
	Unit V: loci 2/18	*23.07*		
	Area 2		*Area 5*	
	Unit I: locus 23	*14.49*	*Unit I: loci 11/12*	*35.82*
	Unit III: locus 1	*21.19*	*Unit II: locus 19*	*14.10*
	Unit IV: locus 7	*7.37*	*Unit IV: locus 13*	*19.13*
	Unit II: locus 20	*7.17*	*Unit III: loci 2/5/7*	*21.15*
Total built area estimate (m^2)				3157.95
			Assessable area (m^2)	*1249.48*
			Assessable built area (m^2)	*789.16*
			Assessable built area as a proportion of assessable area	*0.6316*
			Estimated total site extent (m^2)	*5000*
Residential built area as a proportion of assessable built area				0.3480
			Potential residential built area (m^2)	*274.65*
Total potential residential built area (m^2)				1099.06
Method 3: Total potential dwelling number				**64.03**
Potential residential built area as a proportion of assessable area				0.2198
Total number of contemporaneous dwellings (78%)				49.94
Total population estimate based on nuclear family size:	**Minimum**		**3**	**149.82**
	Average		**5.5**	**274.67**
	Maximum		**8**	**399.53**

Residential area density coefficient (RADC)

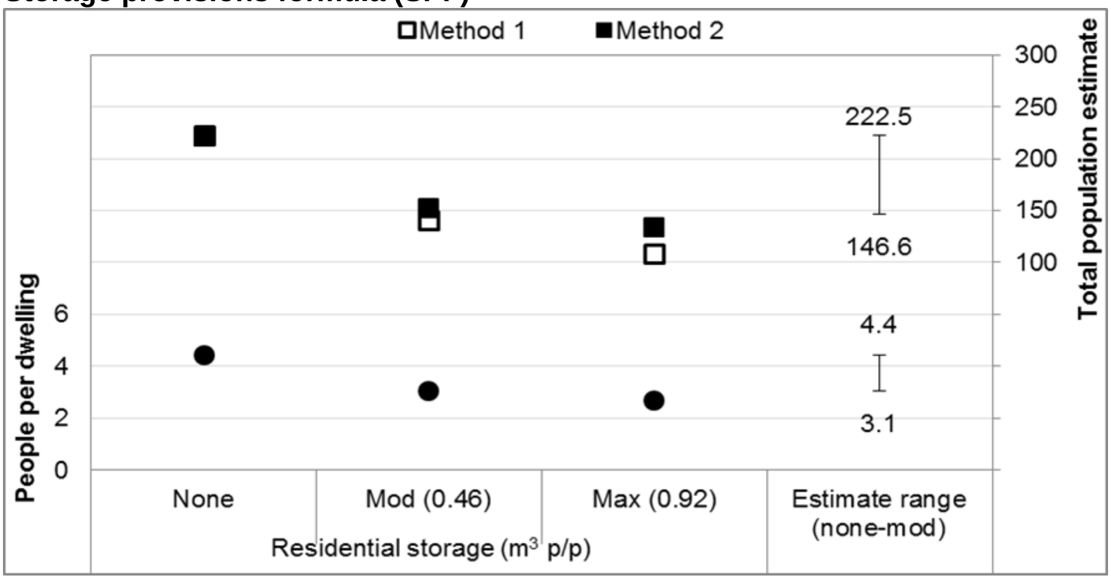
Method 1: Total potential residential floor area (m^2)					**726.38**
Potential residential floor area (m^2)					181.52
Potential residential floor area (m^2)	*Area 1*		*Area 3*		
	Unit I: locus 16	*15.17*	*Unit I: loci 4/5*	*9.25*	
	Unit II: locus 20	*8.45*	*Unit II: locus 13*	*3.02*	
	Unit III: locus 10	*17.51*	*Unit III: loci 11/12*	*7.72*	
	Unit IV: locus 1	*12.61*			
	Unit V: loci 2/18	*15.99*			
	Area 2		*Area 5*		
	Unit I: locus 23	*11.58*	*Unit I: loci 11/12*	*22.79*	
	Unit II: locus 20	*4.80*	*Unit II: locus 19*	*10.98*	
	Unit III: locus 1	*11.95*	*Unit III: loci 2/5/7*	*14.29*	
	Unit IV: locus 7	*4.71*	*Unit IV: locus 13*	*10.70*	
Assessable area (m^2)					1249.48
Estimated total site extent (m^2)					5000
Assessable area (proportion)					0.2499

Method 2: Total potential residential floor area (m^2)	**726.38**
Total built area estimate (m^2)	3157.95
Assessable area (m^2)	*1249.48*
Assessable built area (m^2)	*789.16*
Assessable built area as a proportion of assessable area	*0.6316*
Estimated total site extent (m^2)	*5000*
Potential residential floor area as a proportion of assessable built area	0.2300
Potential residential floor area (m^2)	*181.52*

Method 3: Total potential residential floor area (m^2)	**726.38**
Potential residential floor area as a proportion of assessable area	0.1453
Total contemporaneous residential floor area (m^2) (78%)	566.58

Total population estimate based on RADC (m^2):	**Minimum**	**1.77**	**320.10**
	Average	**3.3**	**171.69**
	Maximum	**5**	**113.32**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	566.58	0.3944 x 566.58	=	223.46	0.2477 x 566.58	=	140.34	0.1903 x 566.58	=	107.82
P	=	?	223.46 - 0.375	=	223.08	140.34 + 0.0339	=	140.38	107.82 + 0.3976	=	108.22
			P	**=**	**223.08**	**P**	**=**	**140.38**	**P**	**=**	**108.22**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	12.22	0.3944 x 12.22	=	4.82	0.2477 x 12.22	=	3.03	0.1903 x 12.22	=	2.33
P	=	?	4.82 - 0.375	=	4.44	3.03 + 0.0339	=	3.06	2.33 + 0.3976	=	2.68
			P	**=**	**4.44**	**P**	**=**	**3.06**	**P**	**=**	**2.68**
						Total number of contemporaneous dwellings					*49.94*
		Total population			**221.97**			**152.86**			**134.08**
Mean total population					**222.52**			**146.62**			**121.15**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (222.52)	*Moderate (146.62)*	*Maximum (121.15)*		*None (222.52)*	*Moderate (146.62)*	*Maximum (121.15)*
Total built floor area (m^2)	2055.10	1446.36	1231.70	1828.16			
Built floor area per person (m^2)	9.24	9.86	10.17		8.22	12.47	15.09
RADC (m^2 per person)	3.67	3.92	4.04		2.55	3.86	4.68
Initial growth index	19.30	27.43	32.21				

Data required		
SPF population estimate (P) based on amount of storage:	None	222.52
	Moderate	146.62
	Maximum	121.15
Residential floor area as a proportion of built floor area (%)		39.73
Total built floor area (m^2) (A)		*1828.16*
Built floor area in assessable area (m^2)		*456.85*
Proportion of site assessable (%)		*24.99*
Total residential floor area (m^2) (RADC method)		*726.38*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	8.22
	Moderate	12.47
	Maximum	15.09
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.55
	Moderate	3.86
	Maximum	4.68
Total contemporaneous residential floor area (m^2) (RADC method)		566.58

$A = a \times P^b$

Amount of storage:							
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 222.52^{0.84195}$**			
	P	=	222.52	$222.52^{0.84195}$		=	94.70
	a	=	21.7	21.7 x 94.7		=	2055.10
	b	=	0.84195	**A**		**=**	**2055.10**
	Built floor area per person (m^2)						**9.24**
	RADC (m^2 per person)						**3.67**
	Residential floor area as a proportion of built floor area						*39.73*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	1828.16	**$1828.16 = a \times 222.52^{0.84195}$**			
	P	=	222.52	$222.52^{0.84195}$		=	94.70
	a	=	?	1828.16/94.7		=	19.30
	b	=	0.84195	***a***		**=**	**19.30**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 146.62^{0.84195}$**			
	P	=	146.62	$146.62^{0.84195}$		=	66.65
	a	=	21.7	21.7 x 66.65		=	1446.36
	b	=	0.84195	**A**		**=**	**1446.36**
	Built floor area per person (m^2)						**9.86**
	RADC (m^2 per person)						**3.92**
	Residential floor area as a proportion of built floor area						*39.73*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	1828.16	**$1828.16 = a \times 146.62^{0.84195}$**			
	P	=	146.62	$146.62^{0.84195}$		=	66.65
	a	=	?	1828.16/66.65		=	27.43
	b	=	0.84195	***a***		**=**	**27.43**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 121.15^{0.84195}$**			
	P	=	121.15	$121.15^{0.84195}$		=	56.76
	a	=	21.7	21.7 x 56.76		=	1231.70
	b	=	0.84195	**A**		**=**	**1231.70**
	Built floor area per person (m^2)						**10.17**
	RADC (m^2 per person)						**4.04**
	Residential floor area as a proportion of built floor area						*39.73*
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	1828.16	**$1828.16 = a \times 121.15^{0.84195}$**			
	P	=	121.15	$121.15^{0.84195}$		=	56.76
	a	=	?	1828.16/56.76		=	32.21
	b	=	0.84195	***a***		**=**	**32.21**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		5000
SPF population estimate (P) based on amount of storage:	None	222.52
	Moderate	146.62
	Maximum	121.15

Amount of storage:		$A = a \times P^b$					
		Open settlements			**5000 = *a* x 222.52^2**		
		A	=	5000			
		P	=	222.52	222.52^2	=	49516.46
		a	=	?	5000/49516.46	=	0.10
		b	=	2	***a***	**=**	**0.10**
		Village settlements			**5000 = *a* x 222.52^1**		
		A	=	5000			
	None	P	=	222.52	222.52^1	=	222.52
		a	=	?	5000/222.52	=	22.5
		b	=	1	***a***	**=**	**22.47**
		Urban settlements			**5000 = *a* x 222.52$^{0.6667}$**		
		A	=	5000			
		P	=	222.52	222.52$^{0.6667}$	=	36.73
		a	=	?	5000/36.73	=	136.14
		b	=	0.6667	***a***	**=**	**136.14**
		Open settlements			**5000 = *a* x 146.62^2**		
		A	=	5000			
		P	=	146.62	146.62^2	=	21496.22
		a	=	?	5000/21496.22	=	0.23
		b	=	2	***a***	**=**	**0.23**
		Village settlements			**5000 = *a* x 146.62^1**		
		A	=	5000			
Amount of storage:	*Moderate*	P	=	146.62	146.62^1	=	146.62
		a	=	?	5000/146.62	=	34.1
		b	=	1	***a***	**=**	**34.10**
		Urban settlements			**5000 = *a* x 146.62$^{0.6667}$**		
		A	=	5000			
		P	=	146.62	146.62$^{0.6667}$	=	27.81
		a	=	?	5000/27.81	=	179.79
		b	=	0.6667	***a***	**=**	**179.79**
		Open settlements			**5000 = *a* x 121.15^2**		
		A	=	5000			
		P	=	121.15	121.15^2	=	14676.72
		a	=	?	5000/14676.72	=	0.34
		b	=	2	***a***	**=**	**0.34**
		Village settlements			**5000 = *a* x 121.15^1**		
		A	=	5000			
	Maximum	P	=	121.15	121.15^1	=	121.15
		a	=	?	5000/121.15	=	41.3
		b	=	1	***a***	**=**	**41.27**
		Urban settlements			**5000 = *a* x 121.15$^{0.6667}$**		
		A	=	5000			
		P	=	121.15	121.15$^{0.6667}$	=	24.49
		a	=	?	5000/24.49	=	204.19
		b	=	0.6667	***a***	**=**	**204.19**

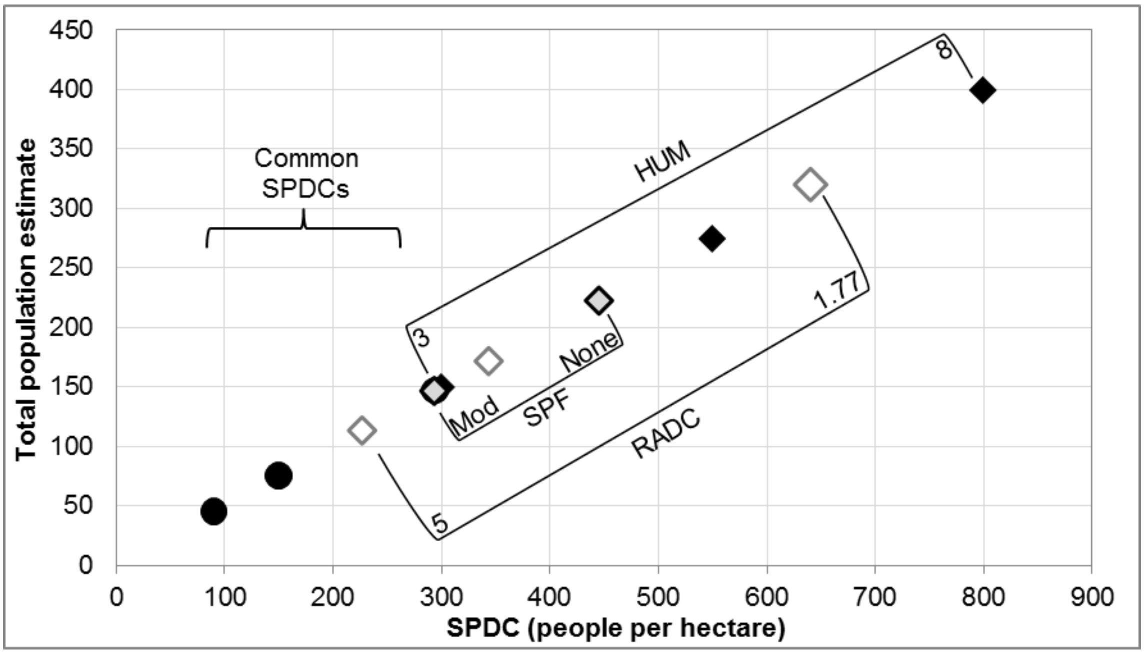
Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (222.52)	*Moderate (146.62)*	*Maximum (121.15)*
Open	0.10	0.23	0.34
Village	22.47	34.10	41.27
Urban	136.14	179.79	204.19

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	0.5
Proportion of site assessable (%)	24.99
Number of contemporaneous dwellings in the assessable area	12.48
Dwellings in assessable area	*16*
Contemporaneity value (%)	*78*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	45	75	147
Population in the assessable area	*11.25*	*18.74*	*36.73*
People per dwelling in the assessable area	*0.90*	*1.50*	*2.94*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	149.82	274.67	399.53	299.64	549.34	799.05
RADC	113.32	171.69	320.10	226.63	343.38	640.20
SPF	146.62	-	222.52	293.24	-	445.04



’Ain Abu Nekheileh

Assessable area (m^2)	Assessable area	136.02
	Unassessable area	0.72
	Total	**135.30**
Potential residential built area (m^2)	Locus 1	6.22
	Locus 2	13.97
	Locus 3	14.05
	Locus 4	5.09
	Locus 5*	15.30
	Locus 11[a]	16.75
	Locus 20*	14.83
	Locus 22*	13.27
	Locus 25	14.10
	Total	**113.59**
	Mean	12.62
	SD (±)	4.08
	*Mean residential built area: complete dwellings	14.47
Potential non-residential built area (m^2)	Loci 21/23/26	12.66
	Undesignated loci	2.91
	Total	**15.57**
Built area (m^2)	Potential residential built area	113.59
	Potential non-residential built area	15.57
	Total	**129.16**

Potential residential floor area (m^2)	Locus 1	4.36
	Locus 2*	7.04
	Locus 3	7.97
	Locus 4	2.85
	Locus 5*	8.19
	Locus 11	11.82
	Locus 20*	9.37
	Locus 22*	6.28
	Locus 25*	9.01
	Total	**66.88**
	*Mean residential floor area: complete dwellings	7.98
Built floor area (m^2)	Locus 1	4.36
	Locus 2	7.04
	Locus 3	7.97
	Locus 4	2.85
	Locus 5	8.19
	Locus 11	11.82
	Locus 20	9.37
	Locus 21	2.56
	Locus 22	6.28
	Locus 23	1.05
	Locus 25	9.01
	Locus 26	1.69
	Undesignated loci	0.84
	Total	**73.02**

[a] Northern boundary of Locus 11 is not defined in the original site plan and, therefore, cannot be assessed as a complete structure.

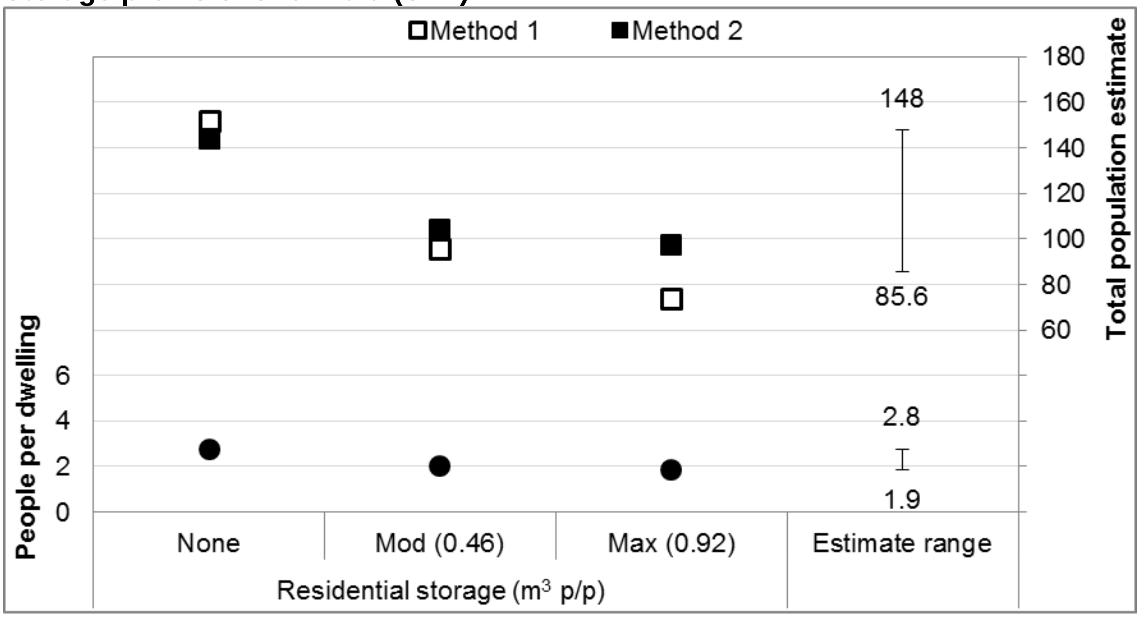
Housing unit method (HUM)

Method 1: Total potential dwelling number					**79.82**
Number of potential dwellings in the assessable area					9
Assessable area (m^2)					135.3
Estimated total site extent (m^2)					1200
Assessable area (proportion)					0.1128
Method 2: Total potential dwelling number					**79.82**
Mean potential residential built area (m^2)					12.62
Potential residential built area (m^2)	*Locus 1*	*6.22*	*Locus 11*		*16.75*
	Locus 2	*13.97*	*Locus 20*		*14.83*
	Locus 3	*14.05*	*Locus 22*		*13.27*
	Locus 4	*5.09*	*Locus 25*		*14.10*
	Locus 5	*15.30*			
Total built area estimate (m^2)					1145.54
				Assessable area (m^2)	*135.3*
				Assessable built area (m^2)	*129.16*
				Assessable built area as a proportion of assessable area	*0.9546*
				Estimated total site extent (m^2)	*1200*
Residential built area as a proportion of assessable built area					0.8794
				Potential residential built area (m^2)	*113.59*
Total potential residential built area (m^2)					1007.41
Method 3: Total potential dwelling number					**79.82**
Potential residential built area as a proportion of assessable area					0.8395
Total number of contemporaneous dwellings (65%)					51.88
Total population estimate based on nuclear family size:	**Minimum**	**3**			**155.65**
	Average	**5.5**			**285.37**
	Maximum	**8**			**415.08**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)					**593.16**
Potential residential floor area (m^2)					66.88
Potential residential floor area (m^2)	*Locus 1*	*4.36*	*Locus 11*		*11.82*
	Locus 2	*7.04*	*Locus 20*		*9.37*
	Locus 3	*7.97*	*Locus 22*		*6.28*
	Locus 4	*2.85*	*Locus 25*		*9.01*
	Locus 5	*8.19*			
Assessable area (m^2)					135.3
Estimated total site extent (m^2)					1200
Assessable area (proportion)					0.1128
Method 2: Total potential residential floor area (m^2)					**593.16**
Total built area estimate (m^2)					1145.54
				Assessable area (m^2)	*135.3*
				Assessable built area (m^2)	*129.16*
				Assessable built area as a proportion of assessable area	*0.9546*
				Estimated total site extent (m^2)	*1200*
Potential residential floor area as a proportion of assessable built area					0.5178
				Potential residential floor area (m^2)	*66.88*
Method 3: Total potential residential floor area (m^2)					**593.16**
Potential residential floor area as a proportion of assessable area					0.4943
Total contemporaneous residential floor area (m^2) (65%)					385.56
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**			**217.83**
	Average	**3.3**			**116.83**
	Maximum	**5**			**77.11**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None			*Moderate (0.46)*			*Maximum (2 x 0.46)*		
			P = 0.3944A – 0.375			*P = 0.2477A + 0.0339*			*P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	385.56	0.3944 x 385.56	=	152.06	0.2477 x 385.56	=	95.50	0.1903 x 385.56	=	73.37
P	=	?	152.06 - 0.375	=	151.69	95.5 + 0.0339	=	95.54	73.37 + 0.3976	=	73.77
			P	**=**	**151.69**	**P**	**=**	**95.54**	**P**	**=**	**73.77**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	7.98	0.3944 x 7.98	=	3.15	0.2477 x 7.98	=	1.98	0.1903 x 7.98	=	1.52
P	=	?	3.15 - 0.375	=	2.77	1.98 + 0.0339	=	2.01	1.52 + 0.3976	=	1.88
			P	**=**	**2.77**	**P**	**=**	**2.01**	**P**	**=**	**1.88**
						Total number of contemporaneous dwellings					*51.88*
		Total population			**143.84**			**104.32**			**97.43**
Mean total population					**147.76**			**99.93**			**85.6**

Naroll's (1962) AGF1

Summary of estimates based on	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount of storage:				*SPF population estimate based on amount of storage:*		
	None (147.76)	*Moderate (99.93)*	*Maximum (85.6)*		*None (147.76)*	*Moderate (99.93)*	*Maximum (85.6)*
Total built floor area (m^2)	1455.89	1047.35	919.42	647.63			
Built floor area per person (m^2)	9.85	10.48	10.74		4.38	6.48	7.57
RADC (m^2 per person)	9.02	9.60	9.84		2.61	3.86	4.50
Initial growth index	9.65	13.42	15.29				

Data required		
SPF population estimate (P) based on amount of storage:	None	147.76
	Moderate	99.93
	Maximum	85.60
Residential floor area as a proportion of built floor area (%)		91.59
Total built floor area (m^2) (A)		*647.63*
Built floor area in assessable area (m^2)		*73.02*
Proportion of site assessable (%)		*11.28*
Total residential floor area (m^2) (RADC method)		*593.16*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	4.38
	Moderate	6.48
	Maximum	7.57
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.61
	Moderate	3.86
	Maximum	4.50
Total contemporaneous residential floor area (m^2) (RADC method)		385.56

$A = a \times P^b$								
Amount of storage:	*None*	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
		A	=	?	**$A = 21.7 \times 147.76^{0.84195}$**			
		P	=	147.76	$147.76^{0.84195}$		=	67.09
		a	=	21.7	21.7 x 67.09		=	1455.89
		b	=	0.84195	**A**		**=**	**1455.89**
		Built floor area per person (m^2)						**9.85**
		RADC (m^2 per person)						**9.02**
					Residential floor area as a proportion of built floor area			*91.59*
		Method 2: Re-calculated initial growth index (*a*)						
		A	=	647.63	**$647.63 = a \times 147.76^{0.84195}$**			
		P	=	147.76	$147.76^{0.84195}$		=	67.09
		a	=	?	647.63/67.09		=	9.65
		b	=	0.84195	***a***		**=**	**9.65**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
		A	=	?	**$A = 21.7 \times 99.93^{0.84195}$**			
		P	=	99.93	$99.93^{0.84195}$		=	48.26
		a	=	21.7	21.7 x 48.26		=	1047.35
		b	=	0.84195	**A**		**=**	**1047.35**
		Built floor area per person (m^2)						**10.48**
		RADC (m^2 per person)						**9.60**
					Residential floor area as a proportion of built floor area			*91.59*
		Method 2: Re-calculated initial growth index (*a*)						
		A	=	647.63	**$647.63 = a \times 99.93^{0.84195}$**			
		P	=	99.93	$99.93^{0.84195}$		=	48.26
		a	=	?	647.63/48.26		=	13.42
		b	=	0.84195	***a***		**=**	**13.42**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
		A	=	?	**$A = 21.7 \times 85.6^{0.84195}$**			
		P	=	85.60	$85.6^{0.84195}$		=	42.37
		a	=	21.7	21.7 x 42.37		=	919.42
		b	=	0.84195	**A**		**=**	**919.42**
		Built floor area per person (m^2)						**10.74**
		RADC (m^2 per person)						**9.84**
					Residential floor area as a proportion of built floor area			*91.59*
		Method 2: Re-calculated initial growth index (*a*)						
		A	=	647.63	**$647.63 = a \times 85.6^{0.84195}$**			
		P	=	85.60	$85.6^{0.84195}$		=	42.37
		a	=	?	647.63/42.37		=	15.29
		b	=	0.84195	***a***		**=**	**15.29**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		1200
SPF population estimate (P) based on amount of storage:	None	147.76
	Moderate	99.93
	Maximum	85.60

					$A = a \times P^b$		
Amount of storage:	*None*	**Open settlements**			**$1200 = a \times 147.76^2$**		
		A	=	1200			
		P	=	147.76	147.76^2	=	21834.27
		a	=	?	1200/21834.27	=	0.05
		b	=	2	***a***	**=**	**0.05**
		Village settlements			**$1200 = a \times 147.76^1$**		
		A	=	1200			
		P	=	147.76	147.76^1	=	147.76
		a	=	?	1200/147.76	=	8.1
		b	=	1	***a***	**=**	**8.1**
		Urban settlements			**$1200 = a \times 147.76^{0.6667}$**		
		A	=	1200			
		P	=	147.76	$147.76^{0.6667}$	=	27.95
		a	=	?	1200/27.95	=	42.93
		b	=	0.6667	***a***	**=**	**42.93**
	Moderate	**Open settlements**			**$1200 = a \times 99.93^2$**		
		A	=	1200			
		P	=	99.93	99.93^2	=	9985.25
		a	=	?	1200/9985.25	=	0.12
		b	=	2	***a***	**=**	**0.12**
		Village settlements			**$1200 = a \times 99.93^1$**		
		A	=	1200			
		P	=	99.93	99.93^1	=	99.93
		a	=	?	1200/99.93	=	12.0
		b	=	1	***a***	**=**	**12.0**
		Urban settlements			**$1200 = a \times 99.93^{0.6667}$**		
		A	=	1200			
		P	=	99.93	$99.93^{0.6667}$	=	21.54
		a	=	?	1200/21.54	=	55.72
		b	=	0.6667	***a***	**=**	**55.72**
	Maximum	**Open settlements**			**$1200 = a \times 85.6^2$**		
		A	=	1200			
		P	=	85.60	85.6^2	=	7327.59
		a	=	?	1200/7327.59	=	0.16
		b	=	2	***a***	**=**	**0.16**
		Village settlements			**$1200 = a \times 85.6^1$**		
		A	=	1200			
		P	=	85.60	85.6^1	=	85.60
		a	=	?	1200/85.6	=	14.0
		b	=	1	***a***	**=**	**14.0**
		Urban settlements			**$1200 = a \times 85.6^{0.6667}$**		
		A	=	1200			
		P	=	85.60	$85.6^{0.6667}$	=	19.43
		a	=	?	1200/19.43	=	61.77
		b	=	0.6667	***a***	**=**	**61.77**

Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (147.76)	*Moderate (99.93)*	*Maximum (85.6)*
Open	0.05	0.12	0.16
Village	8.12	12.01	14.02
Urban	42.93	55.72	61.77

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	0.12
Proportion of site assessable (%)	11.28
Number of contemporaneous dwellings in the assessable area	5.85
Dwellings in assessable area	*9*
Contemporaneity value (%)	*65*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum 90	*Average 150*	*Maximum 294*
Total population	10.8	18	35.28
Population in the assessable area	*1.22*	*2.03*	*3.98*
People per dwelling in the assessable area	*0.21*	*0.35*	*0.68*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	155.65	-	285.37	1297.12	-	2378.05
RADC	77.11	116.83	217.83	642.59	973.62	1815.23
SPF	85.60	99.93	147.76	713.34	832.72	1231.37

El-Hemmeh (LPPNB)

Assessable area (m^2)	Assessable area		126.82
	Unassessable area		25.44
	Total		**101.38**
Potential residential built area (m^2)	Upper storey	Unit 1*	20.23
		Unit 2*	10.40
		Unit 3	10.32
		Unit 4	11.96
	Total		**52.91**
	Mean		13.23
	SD (±)		4.73
	Mean residential built area: complete dwellings		15.32
Potential non-residential built area (m^2)	Ground floor	Unit 1: spaces 13-15/32	20.23
		Unit 2: space 12/19	20.82
		Unit 3: space 16/17	17.71
		Unit 4: space 20	11.96
		Spaces 21/23/27/30-31 and undesignated space	30.52
	Total		**101.24**

Built area (m^2)	Potential residential built area (ground floor)						-
	Potential non-residential built area						101.24
	Total						**101.24**
				Adjusted[a]			Adjusted
Potential residential floor area (m^2)	Upper storey	Unit 1	16.95	13.98	Unit 3	7.76	6.40
		Unit 2	8.75	7.22	Unit 4	8.55	7.05
	Total					**42.01**	**34.66**
	Mean residential floor area (all complete)					10.50	8.66
Built floor area (m^2)	Ground floor	Unit 1: spaces 13-15/32/?	9.36		Space 21	1.94	
		Unit 2: spaces 12/19/?	9.45		Space 23	2.56	
		Unit 3: spaces 16/17/?	7.54		Space 27	0.87	
		Unit 4: space 20	5.02		Space 30	1.45	
		Undesignated space	3.40		Space 31	1.20	
	Upper storey	Unit 1	16.95	13.98	Unit 3	7.76	6.40
		Unit 2	8.75	7.22	Unit 4	8.55	7.05
	Total					**84.80**	**77.45**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

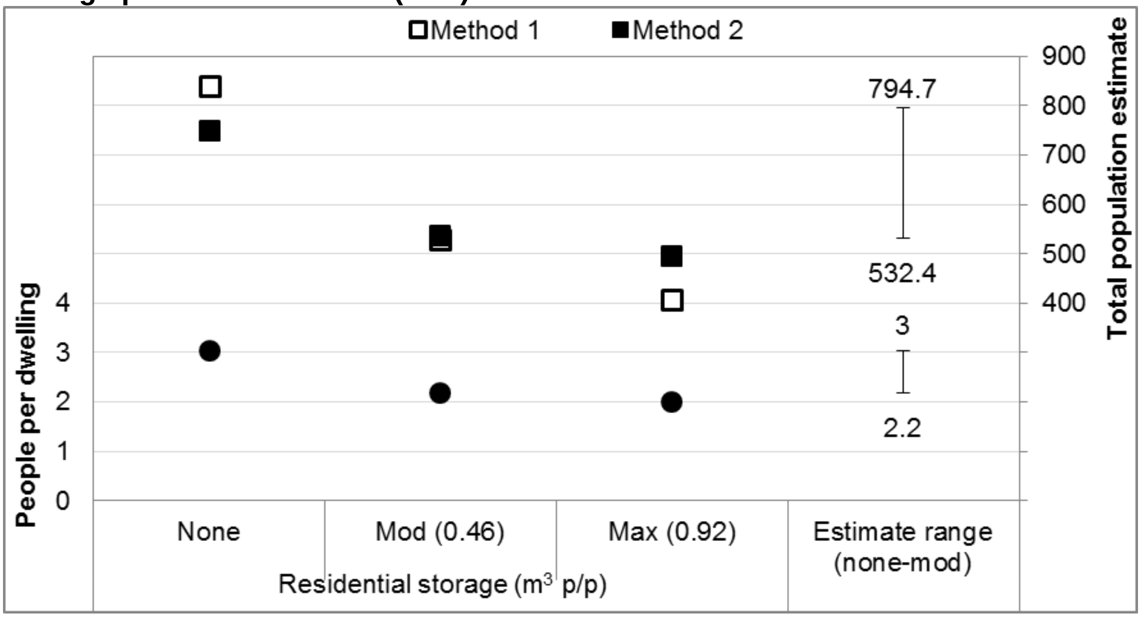
Housing unit method (HUM)

Method 1: Total potential dwelling number					**315.64**
Number of potential dwellings in the assessable area					4
Assessable area (m^2)					101.38
Estimated total site extent (m^2)					8000
Assessable area (proportion)					0.0127
Method 2: Total potential dwelling number					**315.64**
Mean potential residential built area (m^2)					13.23
Potential residential built area (m^2)	*Unit 1*	*20.23*	*Unit 3*		*10.32*
	Unit 2	*10.40*	*Unit 4*		*11.96*
Total built area estimate (m^2)					7988.95
				Assessable area (m^2)	*101.38*
				Assessable built area (m^2)	*101.24*
				Assessable built area as a proportion of assessable area	*0.9986*
				Estimated total site extent (m^2)	*8000*
Residential built area as a proportion of assessable built area					0.5226
				Potential residential built area (m^2)	*52.91*
Total potential residential built area (m^2)					4175.18
Method 3: Total potential dwelling number					**315.64**
Potential residential built area as a proportion of assessable area					0.5219
Total number of contemporaneous dwellings (78%)					246.20
Total population estimate based on nuclear family size:	**Minimum**		**3**		**738.61**
	Average		**5.5**		**1354.11**
	Maximum		**8**		**1969.62**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m²)				**2734.66**
Potential residential floor area (m²)				34.66
Potential residential floor area (m²)	*Unit 1*	*13.98*	*Unit 3*	*6.40*
	Unit 2	*7.22*	*Unit 4*	*7.05*
Assessable area (m²)				101.38
Estimated total site extent (m²)				8000
Assessable area (proportion)				0.0127
Method 2: Total potential residential floor area (m²)				**2734.66**
Total built area estimate (m²)				7988.95
			Assessable area (m²)	*101.38*
			Assessable built area (m²)	*101.24*
			Assessable built area as a proportion of assessable area	*0.9986*
			Estimated total site extent (m²)	*8000*
Potential residential floor area as a proportion of assessable built area				0.3423
			Potential residential floor area (m²)	*34.66*
Method 3: Total potential residential floor area (m²)				**2734.66**
Potential residential floor area as a proportion of assessable area				0.3418
Total contemporaneous residential floor area (m²) (78%)				2133.04
Total population estimate based on RADC (m²):		**Minimum**	**1.77**	**1205.11**
		Average	**3.3**	**646.37**
		Maximum	**5**	**426.61**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None			*Moderate (0.46)*			*Maximum (2 x 0.46)*		
			P = 0.3944A – 0.375			*P = 0.2477A + 0.0339*			*P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	2133.04	0.3944 x 2133.04	=	841.27	0.2477 x 2133.04	=	528.35	0.1903 x 2133.04	=	405.92
P	=	?	841.27 - 0.375	=	840.89	528.35 + 0.0339	=	528.39	405.92 + 0.3976	=	406.31
			P	**=**	**840.89**	**P**	**=**	**528.39**	**P**	**=**	**406.31**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	8.66	0.3944 x 8.66	=	3.42	0.2477 x 8.66	=	2.15	0.1903 x 8.66	=	1.65
P	=	?	3.42 - 0.375	=	3.04	2.15 + 0.0339	=	2.18	1.65 + 0.3976	=	2.01
			P	**=**	**3.04**	**P**	**=**	**2.18**	**P**	**=**	**2.01**
						Total number of contemporaneous dwellings					*246.20*
		Total population			**748.58**			**536.47**			**494.20**
Mean total population					**794.74**			**532.43**			**450.26**

Naroll's (1962) AGF1

Summary of estimates based on:	Naroll's (1962) formula				Archaeological evidence		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (794.74)	*Moderate (532.43)*	*Maximum (450.26)*		*None (794.74)*	*Moderate (532.43)*	*Maximum (450.26)*
Total built floor area (m^2)	6002.09	4283.86	3719.99	6111.66			
Built floor area per person (m^2)	7.55	8.05	8.26		7.69	11.48	13.57
RADC (m^2 per person)	3.38	3.60	3.70		2.68	4.01	4.74
Initial growth index	22.10	30.96	35.65				

Data required		
SPF population estimate (P) based on amount of storage:	None	794.74
	Moderate	532.43
	Maximum	450.26
Residential floor area as a proportion of built floor area (%)		44.74
Total built floor area (m^2) (A)		*6111.66*
Built floor area in assessable area (m^2)		*77.45*
Proportion of site assessable (%)		*1.27*
Total residential floor area (m^2) (RADC method)		*2734.66*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	7.69
	Moderate	11.48
	Maximum	13.57
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.68
	Moderate	4.01
	Maximum	4.74
Total contemporaneous residential floor area (m^2) (RADC method)		2133.04

Amount of storage:		$A = a \times P^b$					
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 794.74^{0.84195}$**			
	P	=	794.74	$794.74^{0.84195}$	=	276.59	
	a	=	21.7	21.7 x 276.59	=	6002.09	
	b	=	0.84195	**A**	**=**	**6002.09**	
	Built floor area per person (m^2)					**7.55**	
	RADC (m^2 per person)					**3.38**	
	Residential floor area as a proportion of built floor area					*44.74*	
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	6111.66	**$6111.66 = a \times 794.74^{0.84195}$**			
	P	=	794.74	$794.74^{0.84195}$	=	276.59	
	a	=	?	6111.66/276.59	=	22.10	
	b	=	0.84195	***a***	**=**	**22.10**	
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 532.43^{0.84195}$**			
	P	=	532.43	$532.43^{0.84195}$	=	197.41	
	a	=	21.7	21.7 x 197.41	=	4283.86	
	b	=	0.84195	**A**	**=**	**4283.86**	
	Built floor area per person (m^2)					**8.05**	
	RADC (m^2 per person)					**3.60**	
	Residential floor area as a proportion of built floor area					*44.74*	
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	6111.66	**$6111.66 = a \times 532.43^{0.84195}$**			
	P	=	532.43	$532.43^{0.84195}$	=	197.41	
	a	=	?	6111.66/197.41	=	30.96	
	b	=	0.84195	***a***	**=**	**30.96**	
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**						
	A	=	?	**$A = 21.7 \times 450.26^{0.84195}$**			
	P	=	450.26	$450.26^{0.84195}$	=	171.43	
	a	=	21.7	21.7 x 171.43	=	3719.99	
	b	=	0.84195	**A**	**=**	**3719.99**	
	Built floor area per person (m^2)					**8.26**	
	RADC (m^2 per person)					**3.70**	
	Residential floor area as a proportion of built floor area					*44.74*	
	Method 2: Re-calculated initial growth index (*a*)						
	A	=	6111.66	**$6111.66 = a \times 450.26^{0.84195}$**			
	P	=	450.26	$450.26^{0.84195}$	=	171.43	
	a	=	?	6111.66/171.43	=	35.65	
	b	=	0.84195	***a***	**=**	**35.65**	

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		10000
SPF population estimate (P) based on amount of storage:	None	794.74
	Moderate	532.43
	Maximum	450.26

$A = a \times P^b$

Amount of storage:							
None	**Open settlements**			**$10000 = a \times 794.74^2$**			
	A	=	10000				
	P	=	794.74	794.74^2	=	631606.77	
	a	=	?	10000/631606.77	=	0.02	
	b	=	2	***a***	**=**	**0.02**	
	Village settlements			**$10000 = a \times 794.74^1$**			
	A	=	10000				
	P	=	794.74	794.74^1	=	794.74	
	a	=	?	10000/794.74	=	12.6	
	b	=	1	***a***	**=**	**12.58**	
	Urban settlements			**$10000 = a \times 794.74^{0.6667}$**			
	A	=	10000				
	P	=	794.74	$794.74^{0.6667}$	=	85.82	
	a	=	?	10000/85.82	=	116.53	
	b	=	0.6667	***a***	**=**	**116.53**	
Moderate	**Open settlements**			**$10000 = a \times 532.43^2$**			
	A	=	10000				
	P	=	532.43	532.43^2	=	283480.40	
	a	=	?	10000/283480.4	=	0.04	
	b	=	2	***a***	**=**	**0.04**	
	Village settlements			**$10000 = a \times 532.43^1$**			
	A	=	10000				
	P	=	532.43	532.43^1	=	532.43	
	a	=	?	10000/532.43	=	18.8	
	b	=	1	***a***	**=**	**18.78**	
	Urban settlements			**$10000 = a \times 532.43^{0.6667}$**			
	A	=	10000				
	P	=	532.43	$532.43^{0.6667}$	=	65.71	
	a	=	?	10000/65.71	=	152.20	
	b	=	0.6667	***a***	**=**	**152.20**	
Maximum	**Open settlements**			**$10000 = a \times 450.26^2$**			
	A	=	10000				
	P	=	450.26	450.26^2	=	202732.25	
	a	=	?	10000/202732.25	=	0.05	
	b	=	2	***a***	**=**	**0.05**	
	Village settlements			**$10000 = a \times 450.26^1$**			
	A	=	10000				
	P	=	450.26	450.26^1	=	450.26	
	a	=	?	10000/450.26	=	22.2	
	b	=	1	***a***	**=**	**22.21**	
	Urban settlements			**$10000 = a \times 450.26^{0.6667}$**			
	A	=	10000				
	P	=	450.26	$450.26^{0.6667}$	=	58.76	
	a	=	?	10000/58.76	=	170.19	
	b	=	0.6667	***a***	**=**	**170.19**	

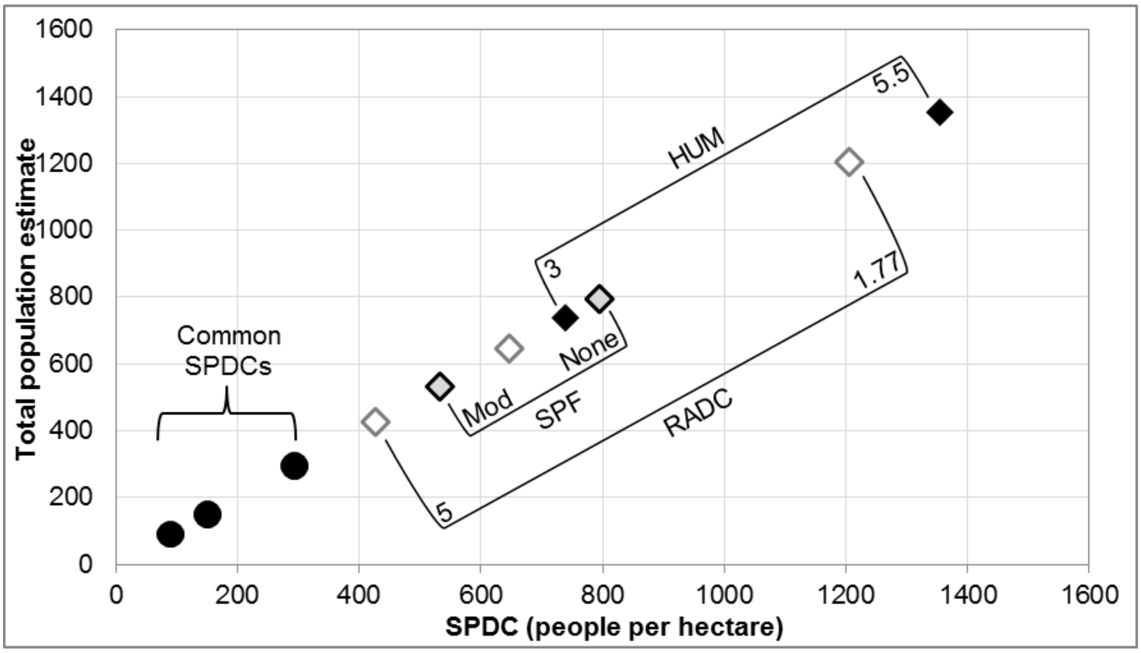
Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (794.74)	*Moderate (532.43)*	*Maximum (450.26)*
Open	0.02	0.04	0.05
Village	12.58	18.78	22.21
Urban	116.53	152.20	170.19

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	1
Proportion of site assessable (%)	1.27
Number of contemporaneous dwellings in the assessable area	3.12
Dwellings in assessable area	*4*
Contemporaneity value (%)	*78*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum 90	*Average 150*	*Maximum 294*
Total population	90	150	294
Population in the assessable area	*1.14*	*1.90*	*3.73*
People per dwelling in the assessable area	*0.37*	*0.61*	*1.19*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	738.61	-	1354.11	738.61	-	1354.11
RADC	426.61	646.37	1205.11	426.61	646.37	1205.11
SPF	532.43	-	794.74	532.43	-	794.74



Basta

Scenario 1: Residential floor area located in the ground floor central room/s only

Assessable area (m^2)		Assessable area	440.90
		Unassessable area	138.39
		Total	**302.51**
Potential residential built area (m^2)	Ground floor	House I*	23.91
		House II*	15.37
		House III*	14.93
		House IV	7.06
		House V*	13.52
		House VII*	11.93
		Total	**86.71**
		Mean	14.45
		SD (±)	5.52
		*Mean residential built area: complete dwellings	16.18
Potential non-residential built area (m^2)	Ground floor	House I	60.56
		House II	36.27
		House III	28.73
		House IV	6.58
		House V	28.72
		House VII	21.25
		Rooms 20-21/Corridor	16.98
		Rooms north and west of House III	16.70
		Total	**215.80**

Built area (m^2)		Potential residential built area	86.71
		Potential non-residential built area	215.80
		Total	**302.51**
Potential residential floor area (m^2)	Ground floor	House I*	16.74
		House II*	10.14
		House III*	11.10
		House IV	5.27
		House V*	8.75
		House VII*	8.48
		Total	**60.48**
		*Mean residential floor area: complete dwellings	11.68
Built floor area (m^2)	Ground floor	House I	43.44
		House II	30.21
		House III	21.09
		House IV	7.61
		House V	19.88
		House VII	20.03
		Rooms 20-21	4.01
		Rooms north and west of House III	10.19
		Total	**156.46**

Housing unit method (HUM)

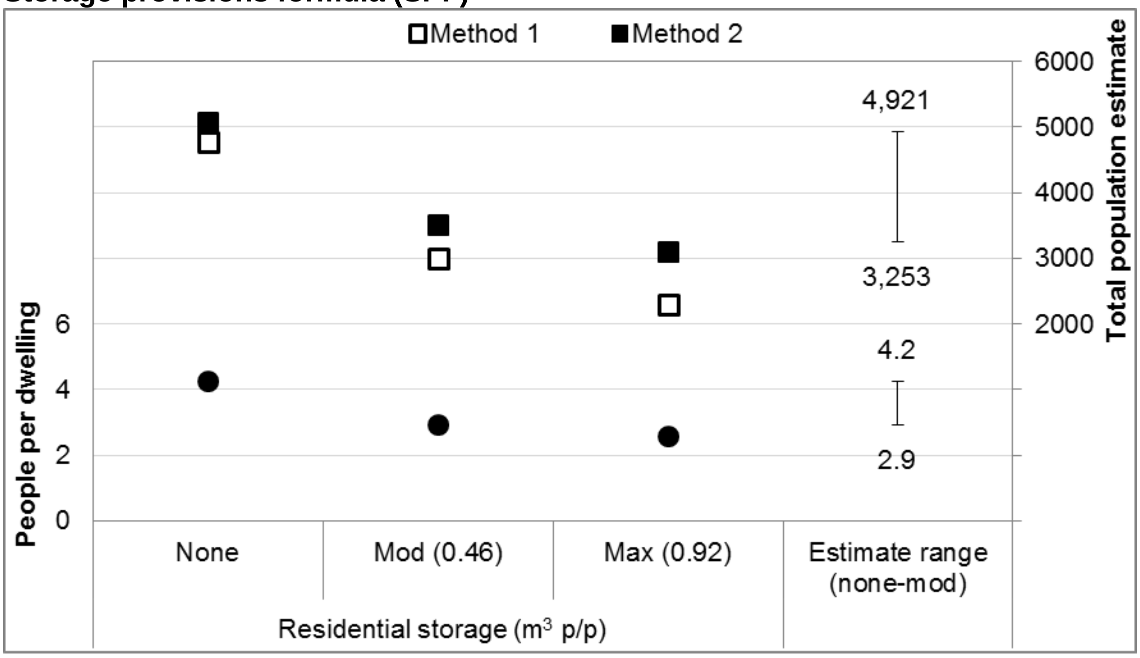
Method 1: Total potential dwelling number					**1983.41**
Number of potential dwellings in the assessable area					6
Assessable area (m^2)					302.51
Estimated total site extent (m^2)					100000
Assessable area (proportion)					0.0030
Method 2: Total potential dwelling number					**1983.41**
Mean potential residential built area (m^2)					14.45
Potential residential built area (m^2)	*House I*	*23.91*	*House IV*		*7.06*
	House II	*15.37*	*House V*		*13.52*
	House III	*14.93*	*House VII*		*11.93*
Total built area estimate (m^2)					100000.00
				Assessable area (m^2)	*302.51*
				Assessable built area (m^2)	*302.51*
				Assessable built area as a proportion of assessable area	*1.0000*
				Estimated total site extent (m^2)	*100000*
Residential built area as a proportion of assessable built area					0.2866
				Potential residential built area (m^2)	*86.71*
Total potential residential built area (m^2)					28663.58
Method 3: Total potential dwelling number					**1983.41**
Potential residential built area as a proportion of assessable area					0.2866
Total number of contemporaneous dwellings (60.47%)					1199.37
Total population estimate based on nuclear family size:		**Minimum**	**3**		**3598.10**
		Average	**5.5**		**6596.51**
		Maximum	**8**		**9594.92**

This method produces the same estimates for Scenario 2 and 3, as it is based on the total number of contemporaneous dwellings, which remains the same for each scenario.

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m²)				**19992.73**
Potential residential floor area (m²)				60.48
Potential residential floor area (m²)	*House I*	*16.74*	*House IV*	*5.27*
	House II	*10.14*	*House VII*	*8.75*
	House III	*11.1*	*House VIII*	*8.48*
Assessable area (m²)				302.51
Estimated total site extent (m²)				100000
Assessable area (proportion)				0.0030
Method 2: Total potential residential floor area (m²)				**19992.73**
Total built area estimate (m²)				100000.00
			Assessable area (m²)	*302.51*
			Assessable built area (m²)	*302.51*
			Assessable built area as a proportion of assessable area	*1.0000*
			Estimated total site extent (m²)	*100000*
Potential residential floor area as a proportion of assessable built area				0.1999
			Potential residential floor area (m²)	*60.48*
Method 3: Total potential residential floor area (m²)				**19992.73**
Potential residential floor area as a proportion of assessable area				0.1999
Total contemporaneous residential floor area (m²) (60.47%)				12089.60
Total population estimate based on RADC (m²):	**Minimum**	**1.77**		**6830.28**
	Average	**3.3**		**3663.52**
	Maximum	**5**		**2417.92**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	12089.60	0.3944 x 12089.6	=	4768.14	0.2477 x 12089.6	=	2994.59	0.1903 x 12089.6	=	2300.65
P	=	?	4768.14 - 0.375	=	4767.76	2994.59 + 0.0339	=	2994.63	2300.65 + 0.3976	=	2301.05
			P	**=**	**4767.76**	**P**	**=**	**2994.63**	**P**	**=**	**2301.05**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	11.68	0.3944 x 11.68	=	4.61	0.2477 x 11.68	=	2.89	0.1903 x 11.68	=	2.22
P	=	?	4.61 - 0.375	=	4.23	2.89 + 0.0339	=	2.93	2.22 + 0.3976	=	2.58
			P	**=**	**4.23**	**P**	**=**	**2.93**	**P**	**=**	**2.58**
						Total number of contemporaneous dwellings					*1199.37*
		Total population			**5075.22**			**3510.59**			**3096.77**
Mean total population					**4921.49**			**3252.61**			**2698.91**

Naroll’s (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**			**Archaeological evidence**			
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (4921.49)	*Moderate (3252.61)*	*Maximum (2698.91)*		*None (4921.49)*	*Moderate (3252.61)*	*Maximum (2698.91)*
Total built floor area (m^2)	27862.55	19659.98	16801.52	51720.60			
Built floor area per person (m^2)	5.66	6.04	6.23		10.51	15.90	19.16
RADC (m^2 per person)	2.19	2.34	2.41		2.46	3.72	4.48
Initial growth index	40.28	57.09	66.80				

Data required		
SPF population estimate (P) based on amount of storage:	None	4921.49
	Moderate	3252.61
	Maximum	2698.91
Residential floor area as a proportion of built floor area (%)		38.66
Total built floor area (m^2) (A)		*51720.60*
Built floor area in assessable area (m^2)		*156.46*
Proportion of site assessable (%)		*0.30*
Total residential floor area (m^2) (RADC method)		*19992.73*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	10.51
	Moderate	15.90
	Maximum	19.16
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.46
	Moderate	3.72
	Maximum	4.48
Total contemporaneous residential floor area (m^2) (RADC method)		12089.60

Amount of storage:	**$A = a \times P^b$**					
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 4921.49^{0.84195}$**		
	P	=	4921.49	$4921.49^{0.84195}$	=	1283.99
	a	=	21.7	21.7 x 1283.99	=	27862.55
	b	=	0.84195	**A**	**=**	**27862.55**
	Built floor area per person (m^2)					**5.66**
	RADC (m^2 per person)					**2.19**
				Residential floor area as a proportion of built floor area		*38.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	51720.60	**$51720.6 = a \times 4921.49^{0.84195}$**		
	P	=	4921.49	$4921.49^{0.84195}$	=	1283.99
	a	=	?	51720.6/1283.99	=	40.28
	b	=	0.84195	***a***	**=**	**40.28**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 3252.61^{0.84195}$**		
	P	=	3252.61	$3252.61^{0.84195}$	=	905.99
	a	=	21.7	21.7 x 905.99	=	19659.98
	b	=	0.84195	**A**	**=**	**19659.98**
	Built floor area per person (m^2)					**6.04**
	RADC (m^2 per person)					**2.34**
				Residential floor area as a proportion of built floor area		*38.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	51720.60	**$51720.6 = a \times 3252.61^{0.84195}$**		
	P	=	3252.61	$3252.61^{0.84195}$	=	905.99
	a	=	?	51720.6/905.99	=	57.09
	b	=	0.84195	***a***	**=**	**57.09**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 2698.91^{0.84195}$**		
	P	=	2698.91	$2698.91^{0.84195}$	=	774.26
	a	=	21.7	21.7 x 774.26	=	16801.52
	b	=	0.84195	**A**	**=**	**16801.52**
	Built floor area per person (m^2)					**6.23**
	RADC (m^2 per person)					**2.41**
				Residential floor area as a proportion of built floor area		*38.66*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	51720.60	**$51720.6 = a \times 2698.91^{0.84195}$**		
	P	=	2698.91	$2698.91^{0.84195}$	=	774.26
	a	=	?	51720.6/774.26	=	66.80
	b	=	0.84195	***a***	**=**	**66.80**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		130000
SPF population estimate (P) based on amount of storage:	None	4921.49
	Moderate	3252.61
	Maximum	2698.91

$A = a \times P^b$

Amount of storage:							
None	**Open settlements**			**$130000 = a \times 4921.49^2$**		
	A	=	130000			
	P	=	4921.49	4921.49^2	=	24221107.18
	a	=	?	130000/24221107.18	=	0.01
	b	=	2	***a***	**=**	**0.01**
	Village settlements			**$130000 = a \times 4921.49^1$**		
	A	=	130000			
	P	=	4921.49	4921.49^1	=	4921.49
	a	=	?	130000/4921.49	=	26.4
	b	=	1	***a***	**=**	**26.41**
	Urban settlements			**$130000 = a \times 4921.49^{0.6667}$**		
	A	=	130000			
	P	=	4921.49	$4921.49^{0.6667}$	=	289.42
	a	=	?	130000/289.42	=	449.18
	b	=	0.6667	***a***	**=**	**449.18**
Moderate	**Open settlements**			**$130000 = a \times 3252.61^2$**		
	A	=	130000			
	P	=	3252.61	3252.61^2	=	10579451.77
	a	=	?	130000/10579451.77	=	0.01
	b	=	2	***a***	**=**	**0.01**
	Village settlements			**$130000 = a \times 3252.61^1$**		
	A	=	130000			
	P	=	3252.61	3252.61^1	=	3252.61
	a	=	?	130000/3252.61	=	40.0
	b	=	1	***a***	**=**	**39.97**
	Urban settlements			**$130000 = a \times 3252.61^{0.6667}$**		
	A	=	130000			
	P	=	3252.61	$3252.61^{0.6667}$	=	219.59
	a	=	?	130000/219.59	=	592.02
	b	=	0.6667	***a***	**=**	**592.02**
Maximum	**Open settlements**			**$130000 = a \times 2698.91^2$**		
	A	=	130000			
	P	=	2698.91	2698.91^2	=	7284101.56
	a	=	?	130000/7284101.56	=	0.02
	b	=	2	***a***	**=**	**0.02**
	Village settlements			**$130000 = a \times 2698.91^1$**		
	A	=	130000			
	P	=	2698.91	2698.91^1	=	2698.91
	a	=	?	130000/2698.91	=	48.2
	b	=	1	***a***	**=**	**48.17**
	Urban settlements			**$130000 = a \times 2698.91^{0.6667}$**		
	A	=	130000			
	P	=	2698.91	$2698.91^{0.6667}$	=	193.90
	a	=	?	130000/193.9	=	670.46
	b	=	0.6667	***a***	**=**	**670.46**

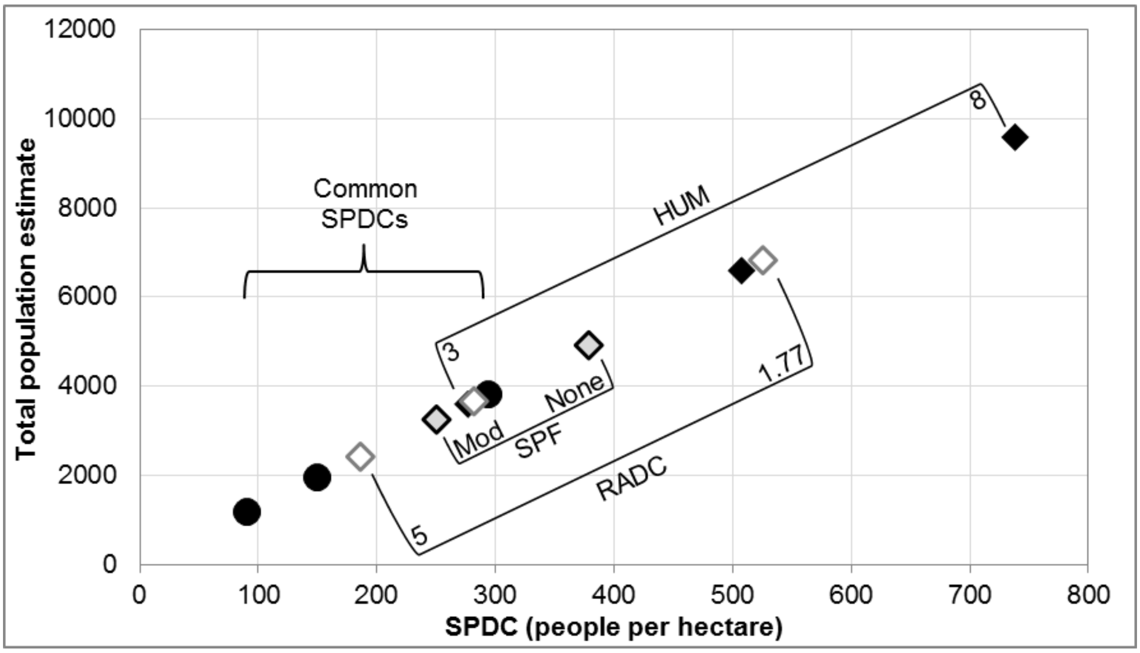
Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (4921.49)	*Moderate (3252.61)*	*Maximum (2698.91)*
Open	0.01	0.01	0.02
Village	26.41	39.97	48.17
Urban	449.18	592.02	670.46

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	13
Proportion of site assessable (%)	0.30
Number of contemporaneous dwellings in the assessable area	3.63
Dwellings in assessable area	*6*
Contemporaneity value (%)	*60.47*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	1170	1950	3822
Population in the assessable area	*3.54*	*5.90*	*11.56*
People per dwelling in the assessable area	*0.98*	*1.63*	*3.19*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	3598.10	6596.51	9594.92	276.78	507.42	738.07
RADC	2417.92	3663.52	6830.28	185.99	281.81	525.41
SPF	3252.61	-	4921.49	250.20	-	378.58



Summary of estimates

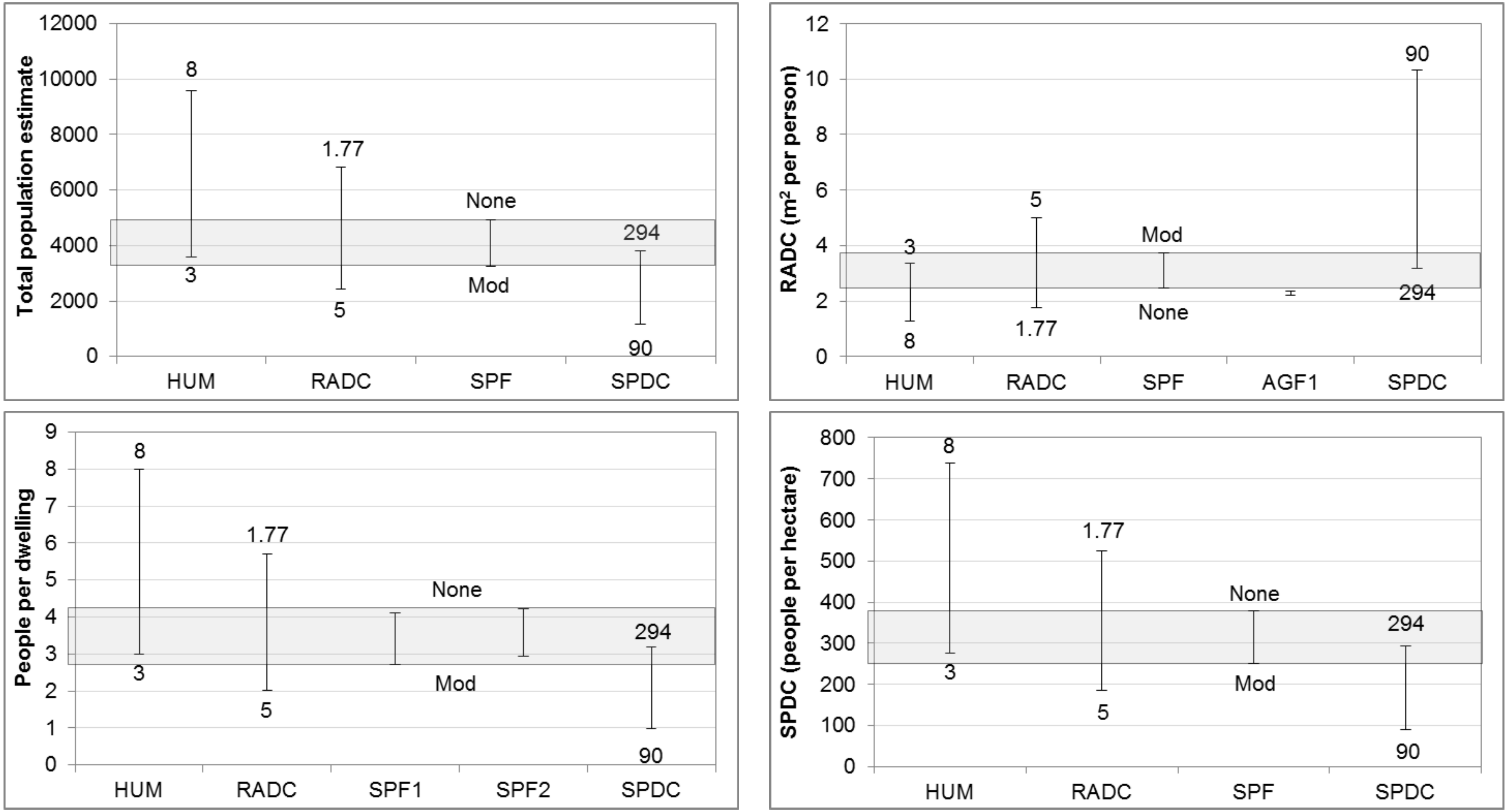
Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		1199.37	*12089.60*	*13*
HUM	3598.1-9594.92	3-8	1.26-3.36	276.78-738.07
RADC	2417.92-6830.28	2.02-5.69	1.77-5.00	185.99-525.41
SPF1	3252.61-4921.49	2.71-4.1	2.46-3.72	250.2-378.58
SPF2[a]	-	2.93-4.23	-	-
AGF1[a]	-	-	2.19-2.34	-
SPDC	1170-3822	0.98-3.19	3.16-10.33	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:**		
		None (4921.49)	*Moderate (3252.61)*	*Maximum (2698.91)*
Naroll's (1962) AGF1		40.28	57.09	66.80
Wiessner's (1974) AGF2	Open settlements	0.01	0.01	0.02
	Village settlements	26.41	39.97	48.17
	Urban settlements	449.18	592.02	670.46

Additional demographic data			
			Contemporaneous (60.47%)
Proportion (%) of site comprising:	Built area	76.92	46.52
	Residential built area	22.05	13.33
	Built floor area	39.79	24.06
	Residential floor area	15.38	9.3
Proportion (%) of assessable built area comprising:	Residential built area	28.66	
	Built floor area [b]	51.72	
	Residential floor area	19.99	
Proportion (%) of built floor area comprising residential floor area		38.66	
Mean residential floor area of complete dwellings (m^2)		11.68	

[b] Based on assessable built area (302.51 m^2) and built floor area (156.46 m^2).


Total population estimate
12000
10000
8000
6000
4000
2000
0
8
3
1.77
5
None
Mod
294
90
HUM
RADC
SPF
SPDC
RADC (m² per person)
12
10
8
6
4
2
0
90
5
3
Mod
294
None
1.77
8
HUM
RADC
SPF
AGF1
SPDC
People per dwelling
9
8
7
6
5
4
3
2
1
0
8
1.77
None
294
3
Mod
5
90
HUM
RADC
SPF1
SPF2
SPDC
SPDC (people per hectare)
800
700
600
500
400
300
200
100
0
8
1.77
None
294
3
Mod
5
90
HUM
RADC
SPF
SPDC

Scenario 2: Residential floor area located in a second storey covering the smaller compartments only

Assessable area (m^2)	Assessable area		440.90
	Unassessable area		138.39
	Total		**302.51**
Potential residential built area (m^2)	Upper storey	House I*	60.56
		House II	36.27
		House III	28.73
		House IV	6.58
		House V	28.72
		House VII *	21.25
	Total		**182.12**
	Mean		30.35
	SD (±)		17.89
	*Mean residential built area: complete dwellings		40.91
Potential non-residential built area (m^2)	Ground floor	House I	84.47
		House II	51.64
		House III	43.66
		House IV	13.64
		House V	42.24
		House VII	33.18
		Rooms 20-21/Corridor	16.98
		Rooms north and west of House III	16.70
	Total		**302.51**
Built area (m^2)	Potential residential built area (ground floor)		-
	Potential non-residential built area		302.51
	Total		**302.51**

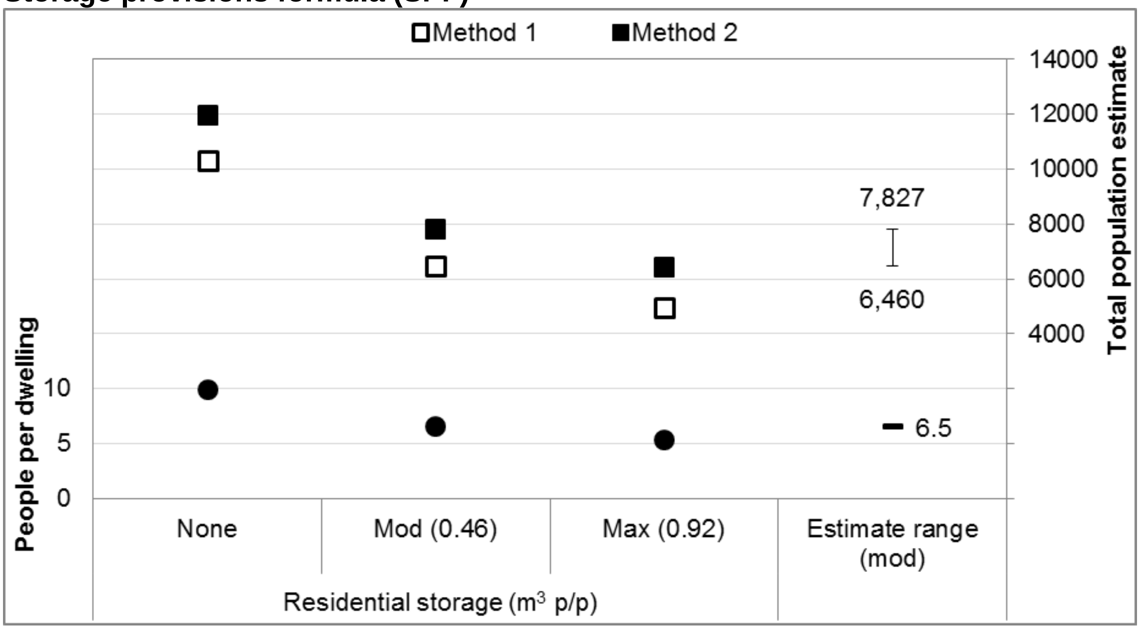
				Adjusted[a]
Potential residential floor area (m^2)	Upper Storey	House I*	53.98	44.54
		House II	32.78	27.04
		House III*	23.40	19.31
		House IV	5.17	4.27
		House V	24.90	20.54
		House VII *	17.91	14.77
	Total		**158.14**	**130.47**
	*Mean residential floor area: complete dwellings		31.76	26.21
Built floor area (m^2)	Ground floor	House I	43.44	
		House II	30.21	
		House III	21.09	
		House IV	7.61	
		House V	19.88	
		House VII	20.03	
		Rooms 20-21	4.01	
		Rooms north and west of House III	10.19	
	Upper Storey	House I	53.98	44.54
		House II	32.78	27.04
		House III	23.40	19.31
		House IV	5.17	4.27
		House V	24.90	20.54
		House VII	17.91	14.77
	Total		**314.60**	**286.92**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)					**43129.15**
Potential residential floor area (m^2)					130.47
Potential residential floor area (m^2)	*House I*	*44.54*	*House IV*		*4.27*
	House II	*27.04*	*House VII*		*20.54*
	House III	*19.31*	*House VIII*		*14.77*
Assessable area (m^2)					302.51
Estimated total site extent (m^2)					100000
Assessable area (proportion)					0.0030
Method 2: Total potential residential floor area (m^2)					**43129.15**
Total built area estimate (m^2)					100000.00
				Assessable area (m^2)	*302.51*
				Assessable built area (m^2)	*302.51*
				Assessable built area as a proportion of assessable area	*1.0000*
				Estimated total site extent (m^2)	*100000*
Potential residential floor area as a proportion of assessable built area					0.4313
				Potential residential floor area (m^2)	*130.47*
Method 3: Total potential residential floor area (m^2)					**43129.15**
Potential residential floor area as a proportion of assessable area					0.4313
Total contemporaneous residential floor area (m^2) (60.47%)					26080.20
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**			**14734.58**
	Average	**3.3**			**7903.09**
	Maximum	**5**			**5216.04**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	26080.20	0.3944 x 26080.2	=	10286.03	0.2477 x 26080.2	=	6460.07	0.1903 x 26080.2	=	4963.06
P	=	?	10286.03 - 0.375	=	10285.66	6460.07 + 0.0339	=	6460.10	4963.06 + 0.3976	=	4963.46
			P	**=**	**10285.66**	**P**	**=**	**6460.10**	**P**	**=**	**4963.46**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	26.21	0.3944 x 26.21	=	10.34	0.2477 x 26.21	=	6.49	0.1903 x 26.21	=	4.99
P	=	?	10.34 - 0.375	=	9.96	6.49 + 0.0339	=	6.53	4.99 + 0.3976	=	5.35
			P	**=**	**9.96**	**P**	**=**	**6.53**	**P**	**=**	**5.35**
						Total number of contemporaneous dwellings					*1199.37*
		Total population			**11948.35**			**7827.20**			**6413.08**
Mean total population					**11117.00**			**7143.65**			**5688.27**

Naroll's (1962) AGF1

Summary of estimates based on:	Naroll's (1962) formula				Archaeological evidence		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (11117)	*Moderate (7143.65)*	*Maximum (5688.27)*		*None (11117)*	*Moderate (7143.65)*	*Maximum (5688.27)*
Total built floor area (m^2)	55332.34	38130.08	31474.97	94846.45			
Built floor area per person (m^2)	4.98	5.34	5.53		8.53	13.28	16.67
RADC (m^2 per person)	2.26	2.43	2.52		2.35	3.65	4.58
Initial growth index	37.20	53.98	65.39				

Data required		
SPF population estimate (P) based on amount of storage:	None	11117.00
	Moderate	7143.65
	Maximum	5688.27
Residential floor area as a proportion of built floor area (%)		45.47
Total built floor area (m^2) (A)		*94846.45*
Built floor area in assessable area (m^2)		*286.92*
Proportion of site assessable (%)		*0.30*
Total residential floor area (m^2) (RADC method)		*43129.15*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	8.53
	Moderate	13.28
	Maximum	16.67
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.35
	Moderate	3.65
	Maximum	4.58
Total contemporaneous residential floor area (m^2) (RADC method)		26080.20

Amount of storage:	$A = a \times P^b$					
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 11117^{0.84195}$**		
	P	=	11117.00	$11117^{0.84195}$	=	2549.88
	a	=	21.7	21.7 x 2549.88	=	55332.34
	b	=	0.84195	**A**	**=**	**55332.34**
	Built floor area per person (m^2)					**4.98**
	RADC (m^2 per person)					**2.26**
	Residential floor area as a proportion of built floor area					*45.47*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	94846.45	**$94846.45 = a \times 11117^{0.84195}$**		
	P	=	11117.00	$11117^{0.84195}$	=	2549.88
	a	=	?	94846.45/2549.88	=	37.20
	b	=	0.84195	***a***	**=**	**37.20**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 7143.65^{0.84195}$**		
	P	=	7143.65	$7143.65^{0.84195}$	=	1757.15
	a	=	21.7	21.7 x 1757.15	=	38130.08
	b	=	0.84195	**A**	**=**	**38130.08**
	Built floor area per person (m^2)					**5.34**
	RADC (m^2 per person)					**2.43**
	Residential floor area as a proportion of built floor area					*45.47*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	94846.45	**$94846.45 = a \times 7143.65^{0.84195}$**		
	P	=	7143.65	$7143.65^{0.84195}$	=	1757.15
	a	=	?	94846.45/1757.15	=	53.98
	b	=	0.84195	***a***	**=**	**53.98**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 5688.27^{0.84195}$**		
	P	=	5688.27	$5688.27^{0.84195}$	=	1450.46
	a	=	21.7	21.7 x 1450.46	=	31474.97
	b	=	0.84195	**A**	**=**	**31474.97**
	Built floor area per person (m^2)					**5.53**
	RADC (m^2 per person)					**2.52**
	Residential floor area as a proportion of built floor area					*45.47*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	94846.45	**$94846.45 = a \times 5688.27^{0.84195}$**		
	P	=	5688.27	$5688.27^{0.84195}$	=	1450.46
	a	=	?	94846.45/1450.46	=	65.39
	b	=	0.84195	***a***	**=**	**65.39**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		130000
SPF population estimate (P) based on amount of storage:	None	11117.00
	Moderate	7143.65
	Maximum	5688.27

$A = a \times P^b$

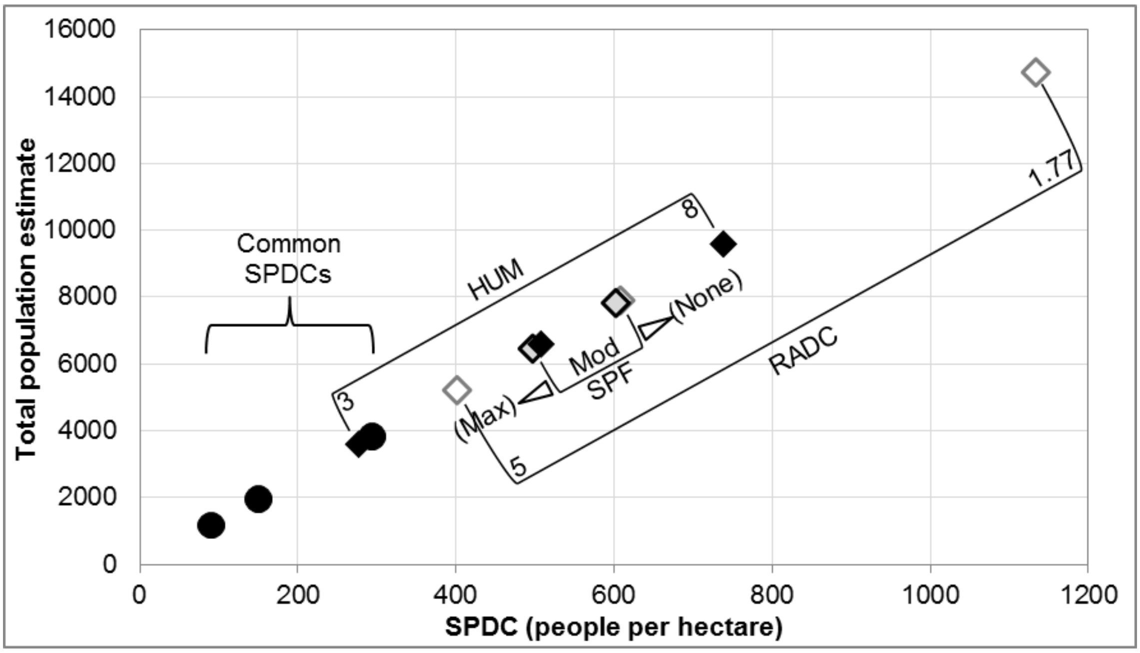
Amount of storage:						
None	**Open settlements**			**$130000 = a \times 11117^2$**		
	A	=	130000			
	P	=	11117.00	11117^2	=	123587702.72
	a	=	?	130000/123587702.72	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 11117^1$**		
	A	=	130000			
	P	=	11117.00	11117^1	=	11117.00
	a	=	?	130000/11117	=	11.7
	b	=	1	***a***	**=**	**11.69**
	Urban settlements			**$130000 = a \times 11117^{0.6667}$**		
	A	=	130000			
	P	=	11117.00	$11117^{0.6667}$	=	498.26
	a	=	?	130000/498.26	=	260.91
	b	=	0.6667	***a***	**=**	**260.91**
Moderate	**Open settlements**			**$130000 = a \times 7143.65^2$**		
	A	=	130000			
	P	=	7143.65	7143.65^2	=	51031717.11
	a	=	?	130000/51031717.11	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 7143.65^1$**		
	A	=	130000			
	P	=	7143.65	7143.65^1	=	7143.65
	a	=	?	130000/7143.65	=	18.2
	b	=	1	***a***	**=**	**18.20**
	Urban settlements			**$130000 = a \times 7143.65^{0.6667}$**		
	A	=	130000			
	P	=	7143.65	$7143.65^{0.6667}$	=	371.03
	a	=	?	130000/371.03	=	350.38
	b	=	0.6667	***a***	**=**	**350.38**
Maximum	**Open settlements**			**$130000 = a \times 5688.27^2$**		
	A	=	130000			
	P	=	5688.27	5688.27^2	=	32356422.88
	a	=	?	130000/32356422.88	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 5688.27^1$**		
	A	=	130000			
	P	=	5688.27	5688.27^1	=	5688.27
	a	=	?	130000/5688.27	=	22.9
	b	=	1	***a***	**=**	**22.85**
	Urban settlements			**$130000 = a \times 5688.27^{0.6667}$**		
	A	=	130000			
	P	=	5688.27	$5688.27^{0.6667}$	=	318.75
	a	=	?	130000/318.75	=	407.85
	b	=	0.6667	***a***	**=**	**407.85**

Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (11117)	*Moderate (7143.65)*	*Maximum (5688.27)*
Open	0.00	0.00	0.00
Village	11.69	18.20	22.85
Urban	260.91	350.38	407.85

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	13

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	3598.10	6596.51	9594.92	276.78	507.42	738.07
RADC	5216.04	7903.09	14734.58	401.23	607.93	1133.43
SPF	6460.10	-	7827.20	496.93	-	602.09



Summary of estimates

Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings:	*Based on total contemporaneous residential floor area (m^2):*	*Based on total site extent (ha):*
		1199.37	*26080.20*	*13*
HUM	3598.1-9594.92	3-8	2.72-7.25	276.78-738.07
RADC	5216.04-14734.58	4.35-12.29	1.77-5.00	401.23-1133.43
SPF1	6460.10-7827.20	5.39-6.53	3.33-4.04	496.93-602.09
SPF2[a]	-	6.53	-	-
AGF1[a]	-	-	2.39-2.47	-
SPDC	1170-3822	0.98-3.19	6.82-22.29	90-294

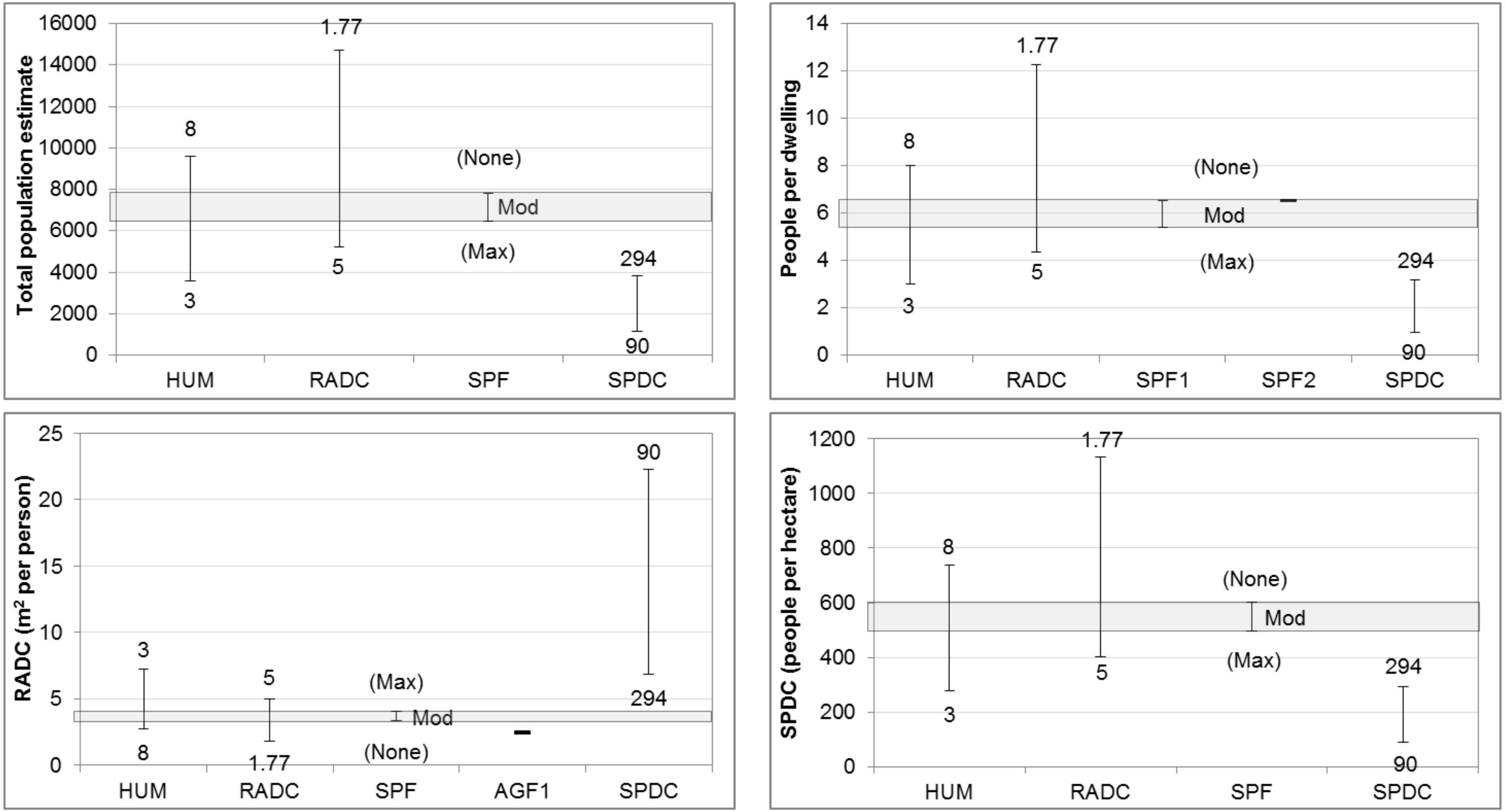
[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		Amount of storage: *None (11117)*	*Moderate (7143.65)*	*Maximum (5688.27)*
Naroll's (1962) AGF1		37.20	53.98	65.39
Wiessner's (1974) AGF2	Open settlements	0.00	0.00	0.00
	Village settlements	11.69	18.20	22.85
	Urban settlements	260.91	350.38	407.85

Additional demographic data

			Contemporaneous (60.47%)
Proportion (%) of site comprising:	Built area	76.92	46.52
	Residential built area	46.31	28.00
	Built floor area	72.96	44.12
	Residential floor area	33.18	20.06
Proportion (%) of assessable built area comprising:	Residential built area	60.20	
	Built floor area[b]	94.85	
	Residential floor area	43.13	
Proportion (%) of built floor area comprising residential floor area		45.47	
Mean residential floor area of complete dwellings (m^2)		26.21	

[b] Based on assessable built area (302.51 m^2) and built floor area (286.92 m^2).



Total population estimate
16000
14000
12000
10000
8000
6000
4000
2000
0
1.77
8
(None)
Mod
(Max)
3
5
294
90
HUM
RADC
SPF
SPDC
People per dwelling
14
12
10
8
6
4
2
0
1.77
8
(None)
Mod
(Max)
5
3
294
90
HUM
RADC
SPF1
SPF2
SPDC
RADC (m² per person)
25
20
15
10
5
0
90
3
5
(Max)
Mod
294
8
1.77
(None)
HUM
RADC
SPF
AGF1
SPDC
SPDC (people per hectare)
1200
1000
800
600
400
200
0
1.77
8
(None)
Mod
(Max)
294
5
3
90
HUM
RADC
SPF
SPDC

Scenario 3: Residential floor area located in the ground floor central room/s and a partial second storey; and (4) a full second storey

Assessable area (m^2)	Assessable area				440.90
	Unassessable area				138.39
	Total				**302.51**
Potential residential built area (m^2)	Ground floor	House I*	23.91	House IV	7.06
		House II	15.37	House V	13.52
		House III	14.93	House VII*	11.93
	Upper storey	House I*	23.31	House V	15.32
		House II	22.40	House VII*	15.06
	Total				**162.80**
	Mean				16.28
	SD (±)				5.39
	*Mean residential built area: complete dwellings				37.11
Potential non-residential built area (m^2)	Ground floor	House I	60.56	House IV	6.82
		House II	36.19	House V	28.52
		House III	28.80	House VII	21.23
		Rooms 20-21/Corridor			16.98
		Rooms north and west of House III			16.70
	Total				**215.80**
Built area (m^2)	Potential residential built area (ground floor)				86.71
	Potential non-residential built area				215.80
	Total				**302.51**

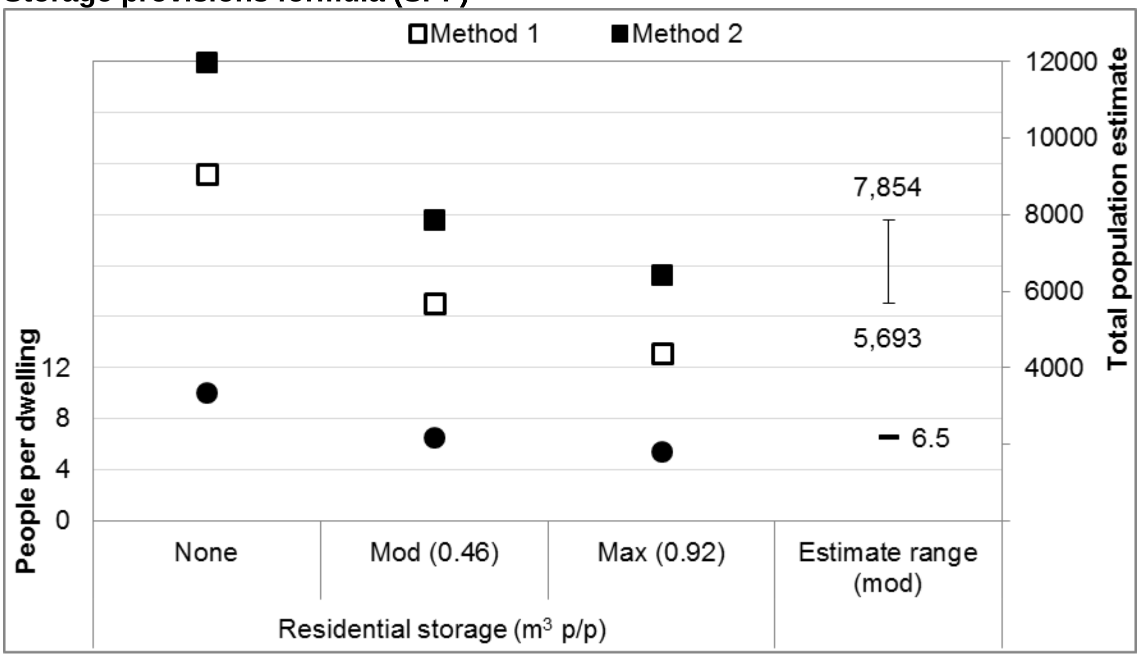
				Adjusted[a]
Potential residential floor area (m^2)	Ground floor	House I*	16.74	
		House II	10.14	
		House III	11.10	
		House IV	5.27	
		House V	8.75	
		House VII*	8.48	
	Upper storey	House I*	20.53	16.94
		House II	20.04	16.53
		House V	12.81	10.57
		House VII*	12.67	10.45
	Total		**126.53**	**114.97**
	*Mean residential floor area: complete dwellings		29.21	26.30
Built floor area (m^2)	Ground floor	House I	43.44	
		House II	30.21	
		House III	21.09	
		House IV	7.61	
		House V	19.88	
		House VII	20.03	
		Rooms 20-21	4.01	
		Rooms north and west of House III	10.19	
	Upper storey	House I*	20.53	16.94
		House II*	20.04	16.53
		House V*	12.81	10.57
		House VII*	12.67	10.45
	Total		**222.51**	**210.95**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)				**38004.63**
Potential residential floor area (m^2)				114.97
Potential residential floor area (m^2)	*House I*	*33.67*	*House IV*	*5.27*
	House II	*26.67*	*House VII*	*19.32*
	House III	*11.10*	*House VIII*	*18.93*
Assessable area (m^2)				302.51
Estimated total site extent (m^2)				100000
Assessable area (proportion)				0.0030
Method 2: Total potential residential floor area (m^2)				**38004.63**
Total built area estimate (m^2)				100000.00
Assessable area (m^2)				*302.51*
Assessable built area (m^2)				*302.51*
Assessable built area as a proportion of assessable area				*1.0000*
Estimated total site extent (m^2)				*100000*
Potential residential floor area as a proportion of assessable built area				0.3800
Potential residential floor area (m2)				*114.97*
Method 3: Total potential residential floor area (m^2)				**38004.63**
Potential residential floor area as a proportion of assessable area				0.3800
Total contemporaneous residential floor area (m^2) (60.47%)				22981.40
Total population estimate based on RADC (m^2):	**Minimum**	**1.77**		**12983.84**
	Average	**3.3**		**6964.06**
	Maximum	**5**		**4596.28**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	22981.40	0.3944 x 22981.4	=	9063.86	0.2477 x 22981.4	=	5692.49	0.1903 x 22981.4	=	4373.36
P	=	?	9063.86 - 0.375	=	9063.49	5692.49 + 0.0339	=	5692.53	4373.36 + 0.3976	=	4373.76
			P	**=**	**9063.49**	**P**	**=**	**5692.53**	**P**	**=**	**4373.76**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	26.3	0.3944 x 26.23	=	10.37	0.2477 x 26.23	=	6.51	0.1903 x 26.23	=	5.00
P	=	?	10.37 - 0.375	=	10.00	6.51 + 0.0339	=	6.55	5.00 + 0.3976	=	5.36
			P	**=**	**10.00**	**P**	**=**	**6.55**	**P**	**=**	**5.36**
						Total number of contemporaneous dwellings					*1199.37*
		Total population			**11990.92**			**7853.94**			**6433.62**
Mean total population					**10527.20**			**6773.23**			**5403.69**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None *(10527.30)*	*Moderate* *(6773.23)*	*Maximum* *(5403.69)*		*None* *(10527.30)*	*Moderate* *(6773.23)*	*Maximum* *(5403.69)*
Total built floor area (m^2)	52850.14	36458.46	30143.83	69733.23			
Built floor area per person (m^2)	5.02	5.38	5.58		6.62	10.30	12.90
RADC (m^2 per person)	2.74	2.93	3.04		2.18	3.39	4.25
Initial growth index	28.63	41.51	50.20				

Data required		
SPF population estimate (P) based on amount of storage:	None	10527.20
	Moderate	6773.23
	Maximum	5403.69
Residential floor area as a proportion of built floor area (%)		54.50
Total built floor area (m^2) (A)		*69733.23*
Built floor area in assessable area (m^2)		*210.95*
Proportion of site assessable (%)		*0.30*
Total residential floor area (m^2) (RADC method)		*38004.63*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	6.62
	Moderate	10.30
	Maximum	12.90
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.18
	Moderate	3.39
	Maximum	4.25
Total contemporaneous residential floor area (m^2) (RADC method)		22981.40

Amount of storage:	$A = a \times P^b$					
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 10527.20^{0.84195}$**		
	P	=	10527.20	$10527.20^{0.84195}$	=	2435.49
	a	=	21.7	21.7 x 2435.49	=	52850.14
	b	=	0.84195	**A**	**=**	**52850.14**
	Built floor area per person (m^2)					**5.02**
	RADC (m^2 per person)					**2.74**
				Residential floor area as a proportion of built floor area		*54.50*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	69733.23	**$69733.23 = a \times 10527.20^{0.84195}$**		
	P	=	10527.20	$10527.20^{0.84195}$	=	2435.49
	a	=	?	69733.23/2435.49	=	28.63
	b	=	0.84195	***a***	**=**	**28.63**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 6773.23^{0.84195}$**		
	P	=	6773.23	$6773.23^{0.84195}$	=	1680.11
	a	=	21.7	21.7 x 1680.11	=	36458.46
	b	=	0.84195	**A**	**=**	**36458.46**
	Built floor area per person (m^2)					**5.38**
	RADC (m^2 per person)					**2.93**
				Residential floor area as a proportion of built floor area		*54.50*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	69733.23	**$69733.23 = a \times 6773.23^{0.84195}$**		
	P	=	6773.23	$6773.23^{0.84195}$	=	1680.11
	a	=	?	69733.23/1680.11	=	41.51
	b	=	0.84195	***a***	**=**	**41.51**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 5403.69^{0.84195}$**		
	P	=	5403.69	$5403.69^{0.84195}$	=	1389.12
	a	=	21.7	21.7 x 1389.12	=	30143.83
	b	=	0.84195	**A**	**=**	**30143.83**
	Built floor area per person (m^2)					**5.58**
	RADC (m^2 per person)					**3.04**
				Residential floor area as a proportion of built floor area		*54.50*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	69733.23	**$69733.23 = a \times 5403.69^{0.84195}$**		
	P	=	5403.69	$5403.69^{0.84195}$	=	1389.12
	a	=	?	69733.23/1389.12	=	50.20
	b	=	0.84195	***a***	**=**	**50.20**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		130000
SPF population estimate (P) based on amount of storage:	None	10527.20
	Moderate	6773.23
	Maximum	5403.69

$A = a \times P^{b}$

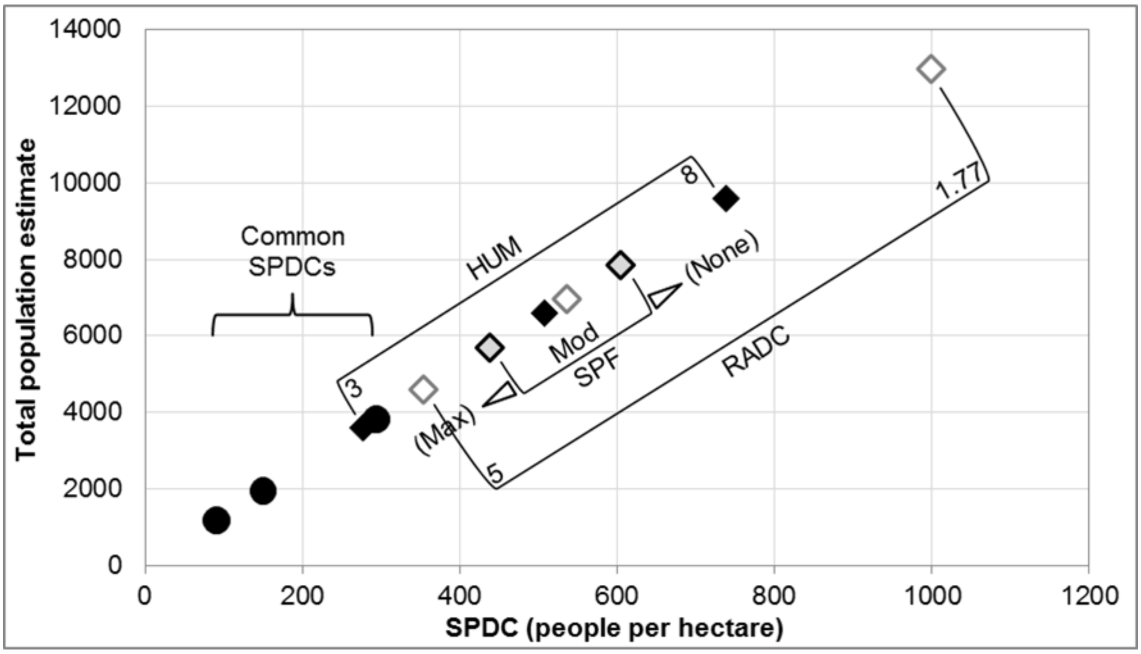
Amount of storage:							
None	**Open settlements**			**$130000 = a \times 10527.20^{2}$**			
	A	=	130000				
	P	=	10527.20	10527.20^{2}	=	110822014.85	
	a	=	?	130000/110822014.85	=	0.00	
	b	=	2	***a***	**=**	**0.00**	
	Village settlements			**$130000 = a \times 10527.20^{1}$**			
	A	=	130000				
	P	=	10527.20	10527.20^{1}	=	10527.20	
	a	=	?	130000/10527.20	=	12.3	
	b	=	1	***a***	**=**	**12.35**	
	Urban settlements			**$130000 = a \times 10527.20^{0.6667}$**			
	A	=	130000				
	P	=	10527.20	$10527.20^{0.6667}$	=	480.48	
	a	=	?	130000/480.48	=	270.56	
	b	=	0.6667	***a***	**=**	**270.56**	
Moderate	**Open settlements**			**$130000 = a \times 6773.23^{2}$**			
	A	=	130000				
	P	=	6773.23	6773.23^{2}	=	45876658.89	
	a	=	?	130000/45876658.89	=	0.00	
	b	=	2	***a***	**=**	**0.00**	
	Village settlements			**$130000 = a \times 6773.23^{1}$**			
	A	=	130000				
	P	=	6773.23	6773.23^{1}	=	6773.23	
	a	=	?	130000/6773.23	=	19.2	
	b	=	1	***a***	**=**	**19.19**	
	Urban settlements			**$130000 = a \times 6773.23^{0.6667}$**			
	A	=	130000				
	P	=	6773.23	$6773.23^{0.6667}$	=	358.09	
	a	=	?	130000/358.09	=	363.04	
	b	=	0.6667	***a***	**=**	**363.04**	
Maximum	**Open settlements**			**$130000 = a \times 5403.69^{2}$**			
	A	=	130000				
	P	=	5403.69	5403.69^{2}	=	29199871.79	
	a	=	?	130000/29199871.79	=	0.00	
	b	=	2	***a***	**=**	**0.00**	
	Village settlements			**$130000 = a \times 5403.69^{1}$**			
	A	=	130000				
	P	=	5403.69	5403.69^{1}	=	5403.69	
	a	=	?	130000/5403.69	=	24.1	
	b	=	1	***a***	**=**	**24.06**	
	Urban settlements			**$130000 = a \times 5403.69^{0.6667}$**			
	A	=	130000				
	P	=	5403.69	$5403.69^{0.6667}$	=	308.02	
	a	=	?	130000/308.02	=	422.04	
	b	=	0.6667	***a***	**=**	**422.04**	

Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (10527.20)	*Moderate (6773.23)*	*Maximum (5403.69)*
Open	0.00	0.00	0.00
Village	12.35	19.19	24.06
Urban	270.56	363.04	422.04

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	13

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	3598.10	6596.51	9594.92	276.78	507.42	738.07
RADC	4596.28	6964.06	12983.84	353.56	535.70	998.76
SPF	5692.53	-	7853.94	437.89	-	604.15



Scenario 4: Residential floor area located in a full second storey

Assessable area (m^2)	Assessable area		440.90
	Unassessable area		138.39
	Total		**302.51**
Potential residential built area (m^2)	Upper storey	House I*	84.47
		House II	51.64
		House III	43.66
		House IV	13.64
		House V	42.24
		House VII*	33.18
	Total		**268.83**
	Mean		44.80
	SD (±)		23.39
	*Mean residential built area: complete dwellings		58.82
Potential non-residential built area (m^2)	Ground floor	House I	84.47
		House II	51.64
		House III	43.66
		House IV	13.64
		House V	42.24
		House VII	33.18
		Rooms 20-21/Corridor	16.98
		Rooms north and west of House III	16.70
	Total		**302.51**
Built area (m^2)	Potential residential built area (ground floor)		-
	Potential non-residential built area		302.51
	Total		**302.51**

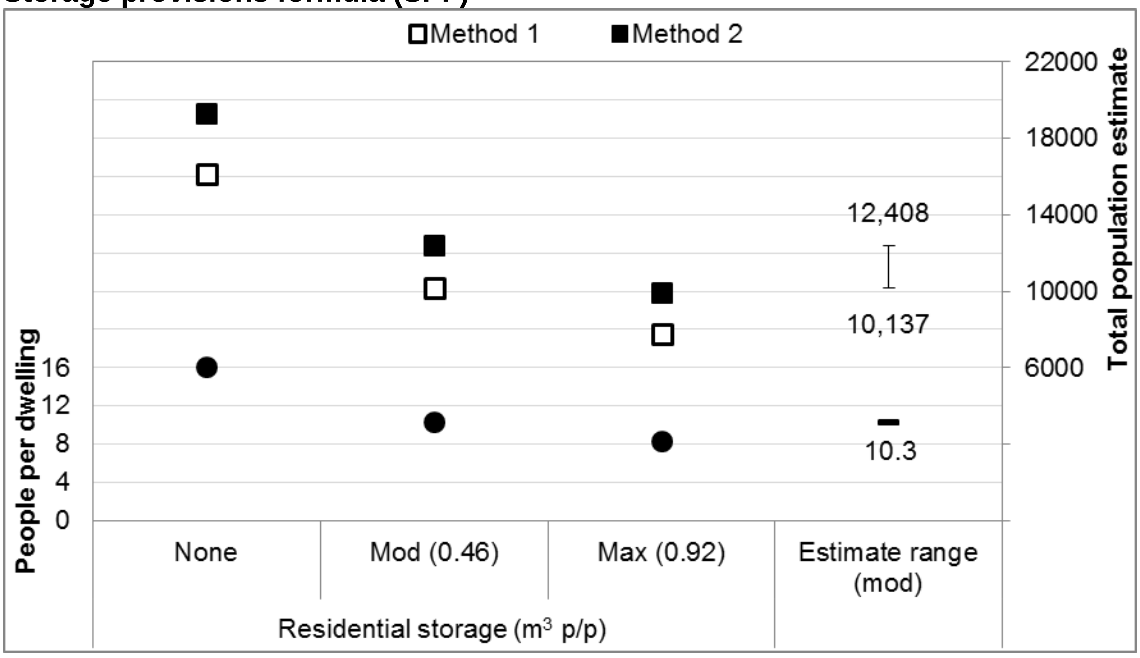
				Adjusted[a]
Potential residential floor area (m^2)	Upper Storey	House I*	77.38	63.84
		House II	47.33	39.05
		House III*	45.29	37.36
		House IV	11.69	9.64
		House V	37.75	31.15
		House VII*	28.71	23.69
	Total		**248.16**	**204.73**
	*Mean residential floor area: complete dwellings		50.46	41.63
Built floor area (m^2)	Ground floor	House I	43.44	
		House II	30.21	
		House III	21.09	
		House IV	7.61	
		House V	19.88	
		House VII	20.03	
		Rooms 20-21	4.01	
		Rooms north and west of House III	10.19	
	Upper Storey	House I	77.38	63.84
		House II	47.33	39.05
		House III	45.29	37.36
		House IV	11.69	9.64
		House V	37.75	31.15
		House VII	28.71	23.69
	Total		**404.61**	**361.19**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)				**67677.10**
Potential residential floor area (m^2)				204.73
Potential residential floor area (m^2)	*House I*	*63.84*	*House IV*	*9.64*
	House II	*39.05*	*House VII*	*31.15*
	House III	*37.36*	*House VIII*	*23.69*
Assessable area (m^2)				302.51
Estimated total site extent (m^2)				100000
Assessable area (proportion)				0.0030
Method 2: Total potential residential floor area (m^2)				**67677.10**
Total built area estimate (m^2)				100000.00
			Assessable area (m^2)	*302.51*
			Assessable built area (m^2)	*302.51*
			Assessable built area as a proportion of assessable area	*1.0000*
			Estimated total site extent (m^2)	*100000*
Potential residential floor area as a proportion of assessable built area				0.6768
			Potential residential floor area (m^2)	*204.73*
Method 3: Total potential residential floor area (m^2)				**67677.10**
Potential residential floor area as a proportion of assessable area				0.6768
Total contemporaneous residential floor area (m^2) (60.47%)				40924.34
Total population estimate based on RADC (m^2):		**Minimum**	**1.77**	**23121.10**
		Average	**3.3**	**12401.32**
		Maximum	**5**	**8184.87**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None			*Moderate (0.46)*			*Maximum (2 x 0.46)*		
			P = 0.3944A – 0.375			*P = 0.2477A + 0.0339*			*P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	40924.34	0.3944 x 26080.2	=	16140.56	0.2477 x 26080.2	=	10136.96	0.1903 x 26080.2	=	7787.90
P	=	?	10286.03 - 0.375	=	16140.19	6460.07 + 0.0339	=	10136.99	4963.06 + 0.3976	=	7788.30
			P	**=**	**16140.19**	**P**	**=**	**10136.99**	**P**	**=**	**7788.30**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	41.63	0.3944 x 26.21	=	16.42	0.2477 x 26.21	=	10.31	0.1903 x 26.21	=	7.92
P	=	?	10.34 - 0.375	=	16.04	6.49 + 0.0339	=	10.35	4.99 + 0.3976	=	8.28
			P	**=**	**16.04**	**P**	**=**	**10.35**	**P**	**=**	**8.28**
						Total number of contemporaneous dwellings					*1199.37*
		Total population			**19242.46**			**12408.21**			**9932.53**
Mean total population					**17691.32**			**11272.60**			**8860.42**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**				**Archaeological evidence**		
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (17691.32)	*Moderate (11272.6)*	*Maximum (8860.42)*		*None (17691.32)*	*Moderate (11272.6)*	*Maximum (8860.42)*
Total built floor area (m^2)	81820.39	55983.70	45710.79	119397.71			
Built floor area per person (m^2)	4.62	4.97	5.16		6.75	10.59	13.48
RADC (m^2 per person)	2.62	2.82	2.92		2.31	3.63	4.62
Initial growth index	31.67	46.28	56.68				

Data required		
SPF population estimate (P) based on amount of storage:	None	17691.32
	Moderate	11272.60
	Maximum	8860.42
Residential floor area as a proportion of built floor area (%)		56.68
Total built floor area (m^2) (A)		*119397.71*
Built floor area in assessable area (m^2)		*361.19*
Proportion of site assessable (%)		*0.30*
Total residential floor area (m^2) (RADC method)		*67677.10*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	6.75
	Moderate	10.59
	Maximum	13.48
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.31
	Moderate	3.63
	Maximum	4.62
Total contemporaneous residential floor area (m^2) (RADC method)		40924.34

$A = a \times P^b$

Amount of storage:						
None	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 17691.32^{0.84195}$**		
	P	=	17691.32	$17691.32^{0.84195}$	=	3770.53
	a	=	21.7	21.7 x 3770.53	=	81820.39
	b	=	0.84195	**A**	**=**	**81820.39**
	Built floor area per person (m^2)					**4.62**
	RADC (m^2 per person)					**2.62**
	Residential floor area as a proportion of built floor area					*56.68*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	119397.71	**$119397.71 = a \times 17691.32^{0.84195}$**		
	P	=	17691.32	$17691.32^{0.84195}$	=	3770.53
	a	=	?	119397.71/3770.53	=	31.67
	b	=	0.84195	***a***	**=**	**31.67**
Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 11272.6^{0.84195}$**		
	P	=	11272.60	$11272.6^{0.84195}$	=	2579.89
	a	=	21.7	21.7 x 2579.89	=	55983.70
	b	=	0.84195	**A**	**=**	**55983.70**
	Built floor area per person (m^2)					**4.97**
	RADC (m^2 per person)					**2.82**
	Residential floor area as a proportion of built floor area					*56.68*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	119397.71	**$119397.71 = a \times 11272.6^{0.84195}$**		
	P	=	11272.60	$11272.6^{0.84195}$	=	2579.89
	a	=	?	119397.71/2579.89	=	46.28
	b	=	0.84195	***A***	**=**	**46.28**
Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
	A	=	?	**$A = 21.7 \times 8860.42^{0.84195}$**		
	P	=	8860.42	$8860.42^{0.84195}$	=	2106.49
	a	=	21.7	21.7 x 2106.49	=	45710.79
	b	=	0.84195	**A**	**=**	**45710.79**
	Built floor area per person (m^2)					**5.16**
	RADC (m^2 per person)					**2.92**
	Residential floor area as a proportion of built floor area					*56.68*
	Method 2: Re-calculated initial growth index (*a*)					
	A	=	119397.71	**$119397.71 = a \times 8860.42^{0.84195}$**		
	P	=	8860.42	$8860.42^{0.84195}$	=	2106.49
	a	=	?	119397.71/2106.49	=	56.68
	b	=	0.84195	***a***	**=**	**56.68**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		130000
SPF population estimate (P) based on amount of storage:	None	17691.32
	Moderate	11272.60
	Maximum	8860.42

$A = a \times P^b$

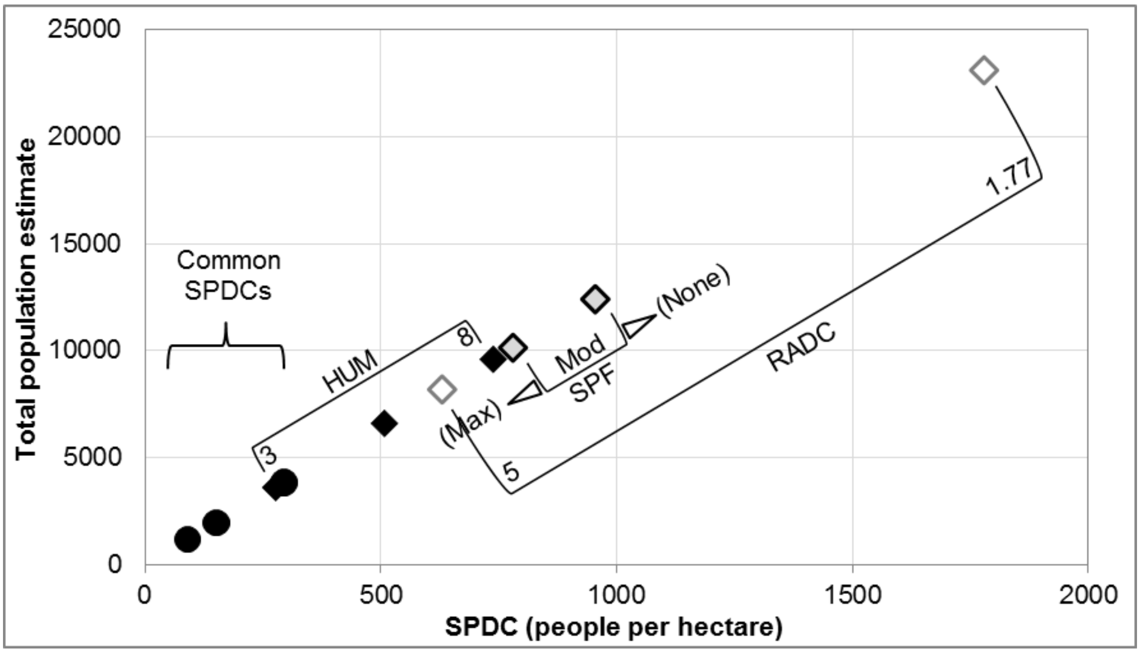
Amount of storage:							
None	**Open settlements**			**$130000 = a \times 17691.31^2$**			
	A	=	130000				
	P	=	17691.32	17691.31^2	=	312982971.89
	a	=	?	130000/312982971.89	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 17691.31^1$**		
	A	=	130000			
	P	=	17691.32	17691.31^1	=	17691.32
	a	=	?	130000/17691.31	=	7.3
	b	=	1	***a***	**=**	**7.35**
	Urban settlements			**$130000 = a \times 17691.31^{0.6667}$**		
	A	=	130000			
	P	=	17691.32	$17691.31^{0.6667}$	=	679.18
	a	=	?	130000/679.18	=	191.41
	b	=	0.6667	***a***	**=**	**191.41**
Moderate	**Open settlements**			**$130000 = a \times 11272.6^2$**		
	A	=	130000			
	P	=	11272.60	11272.6^2	=	127071608.42
	a	=	?	130000/127071608.42	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 11272.6^1$**		
	A	=	130000			
	P	=	11272.60	11272.6^1	=	11272.60
	a	=	?	130000/11272.6	=	11.5
	b	=	1	***a***	**=**	**11.53**
	Urban settlements			**$130000 = a \times 11272.6^{0.6667}$**		
	A	=	130000			
	P	=	11272.60	$11272.6^{0.6667}$	=	502.90
	a	=	?	130000/502.9	=	258.50
	b	=	0.6667	***a***	**=**	**258.50**
Maximum	**Open settlements**			**$130000 = a \times 8860.42^2$**		
	A	=	130000			
	P	=	8860.42	8860.42^2	=	78506960.70
	a	=	?	130000/78506960.70	=	0.00
	b	=	2	***a***	**=**	**0.00**
	Village settlements			**$130000 = a \times 8860.42^1$**		
	A	=	130000			
	P	=	8860.42	8860.42^1	=	8860.42
	a	=	?	130000/8860.42	=	14.7
	b	=	1	***a***	**=**	**14.67**
	Urban settlements			**$130000 = a \times 8860.42^{0.6667}$**		
	A	=	130000			
	P	=	8860.42	$8860.42^{0.6667}$	=	428.32
	a	=	?	130000/428.32	=	303.51
	b	=	0.6667	***a***	**=**	**303.51**

Initial growth indices			
Settlement type	*SPF population estimate based on* amount *of storage:*		
	None (17691.32)	*Moderate (11272.6)*	*Maximum (8860.42)*
Open	0.00	0.00	0.00
Village	7.35	11.53	14.67
Urban	191.41	258.50	303.51

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	13

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	3598.10	6596.51	9594.92	276.78	507.42	738.07
RADC	8184.87	12401.32	23121.10	629.61	953.95	1778.55
SPF	10136.99	-	12408.21	779.77	-	954.48



Summary of estimates

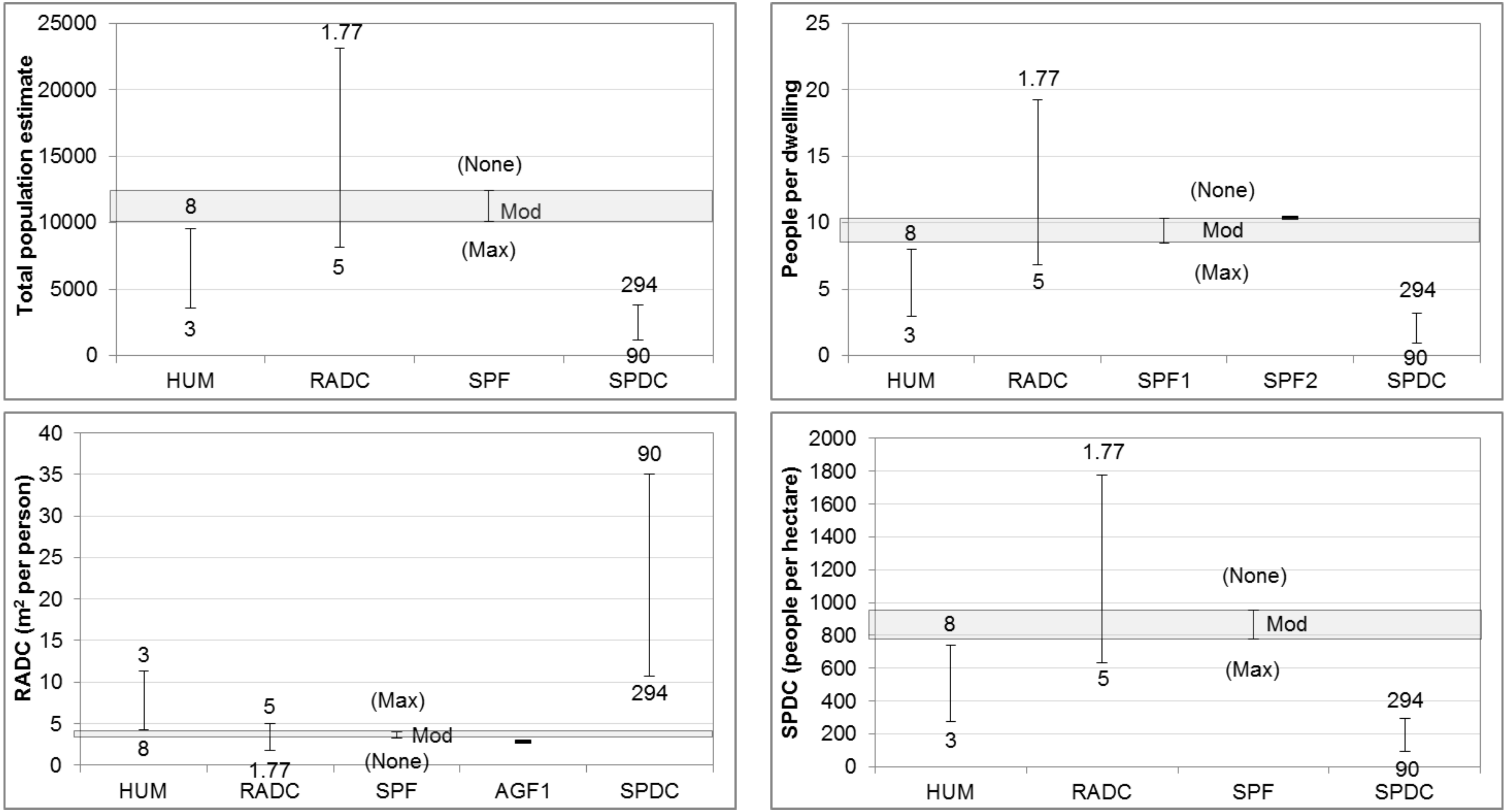
Method	Total population	People per dwelling	RADC (m^2/person)	SPDC (people/ha)
		Based on total number of contemporaneous dwellings: 1199.37	*Based on total contemporaneous residential floor area (m^2): 40924.34*	*Based on total site extent (ha): 13*
HUM	3598.1-9594.92	3-8	4.27-11.37	276.79-738.07
RADC	8184.87-23121.1	6.82-19.28	1.77-5.00	629.61-1778.55
SPF1	10136.99-12408.21	8.45-10.35	3.30-4.04	779.77-954.48
SPF2[a]	-	10.35	-	-
AGF1[a]	-	-	2.77-2.86	-
SPDC	1170-3822	0.98-3.19	10.71-34.98	90-294

[a] Direct calculations.

Initial growth indices derived from SPF population estimates:		**Amount of storage:** *None (17691.32)*	*Moderate (11272.6)*	*Maximum (8860.42)*
Naroll's (1962) AGF1		31.67	46.28	56.68
Wiessner's (1974) AGF2	Open settlements	0.00	0.00	0.00
	Village settlements	7.35	11.53	14.67
	Urban settlements	191.41	285.50	303.51

Additional demographic data			*Contemporaneous (60.47%)*
Proportion (%) of site comprising:	Built area	76.92	46.52
	Residential built area	68.36	41.34
	Built floor area	91.84	55.54
	Residential floor area	52.06	31.48
Proportion (%) of assessable built area comprising:	Residential built area	88.87	
	Built floor area [b]	119.40	
	Residential floor area	67.68	
Proportion (%) of built floor area comprising residential floor area		56.68	
Mean residential floor area of complete dwellings (m^2)		41.63	

[b] Based on assessable built area (302.51 m^2) and built floor area (361.19 m^2).


Total population estimate
25000
20000
15000
10000
5000
0
HUM
RADC
SPF
SPDC
1.77
(None)
8
Mod
(Max)
5
3
294
90
People per dwelling
25
20
15
10
5
0
HUM
RADC
SPF1
SPF2
SPDC
1.77
(None)
8
Mod
5
(Max)
3
294
90
RADC (m² per person)
40
35
30
25
20
15
10
5
0
HUM
RADC
SPF
AGF1
SPDC
90
3
294
5
(Max)
Mod
8
1.77
(None)
SPDC (people per hectare)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
HUM
RADC
SPF
SPDC
1.77
(None)
8
Mod
5
(Max)
3
294
90

Ba’ja

Assessable area (m^2)	Assessable area	Area B North	149.85
		Area C	288.92
		Area D	198.51
	Unassessable area		150.59
	Total		**486.69**

Potential residential built area (m^2)	Ground floor	Unit BVI	7.48		
		Unit CV*	26.96		
	Upper storey	Unit BI*	11.66	Unit CII(*)	44.90
		Unit BIII*	21.89	Unit CVI	47.41
		Unit BIV	19.54	Unit CVII	26.91
		Unit BV*	5.45	Unit DI*	26.22
		Unit BVIII	15.21	Unit DII*	25.34
	Total				**278.97**
	Mean				23.25
	SD (±)				13.05
	*Mean residential built area: complete dwellings				23.20
	((*) marginally incomplete building)				

Potential non-residential built area (m^2)	Ground floor	Unit BI	11.66	Unit CII	59.49
		Unit BII	17.37	Unit CV	18.18
		Unit BIII	34.41	Unit CVI	50.02
		Unit BIV	26.87	Unit CVII	46.11
		Unit BV	7.06	Unit CVIII	3.38
		Unit BVI	6.32	Unit DI	53.35
		Unit BVIII	17.62	Unit DII	57.72
				Area D: W	33.15
	Upper storey	Unit BIV			5.24
		Unit DII			4.67
	Total				**452.62**

Built area (m^2)	Potential residential built area (ground floor)	34.44
	Potential non-residential built area	442.71
	Total	**477.15**

				Adjusted[a]			Adjusted
Potential residential floor area (m^2)	Ground floor	Unit BVI	5.55				
		Unit CV*	19.04				
	Upper storey	Unit BI*	7.93	6.54	Unit CII*	32.09	26.47
		Unit BIII*	16.69	13.77	Unit CVI	32.32	26.66
		Unit BIV*	15.21	12.55	Unit CVII	23.56	19.44
		Unit BV*	3.39	2.80	Unit DI*	18.46	15.23
		Unit BVIII	13.50	11.14	Unit DII*	13.92	11.48
	Total					**201.66**	**170.67**
	*Mean residential floor area: complete dwellings					15.72	13.48

Built floor area (m^2)	Ground floor	Unit BI	3.80		Unit CII	37.47	
		Unit BII	10.55		Unit CV	26.20	
		Unit BIII	15.98		Unit CVI	27.79	
		Unit BIV	12.36		Unit CVII	34.49	
		Unit BV	3.30		Unit DI	29.46	
		Unit BVI	9.00		Unit DII	31.25	
		Unit BVIII	11.81		Area D: W	17.25	
	Upper storey	Unit BI	7.93	6.54	Unit CII	32.09	26.47
		Unit BIII	16.69	13.77	Unit CVI	32.32	26.67
		Unit BIV	18.86	15.56	Unit CVII	23.56	19.44
		Unit BV	3.39	2.79	Unit DI	18.46	15.23
		Unit BVIII	13.50	11.14	Unit DII	18.59	15.33
	Total					**456.10**	**423.66**

[a] Upper storey interior area reduced by 17.5% based on proportion derived for Beidha Subphase C2 (17.42%) (see Section 5.2.2).

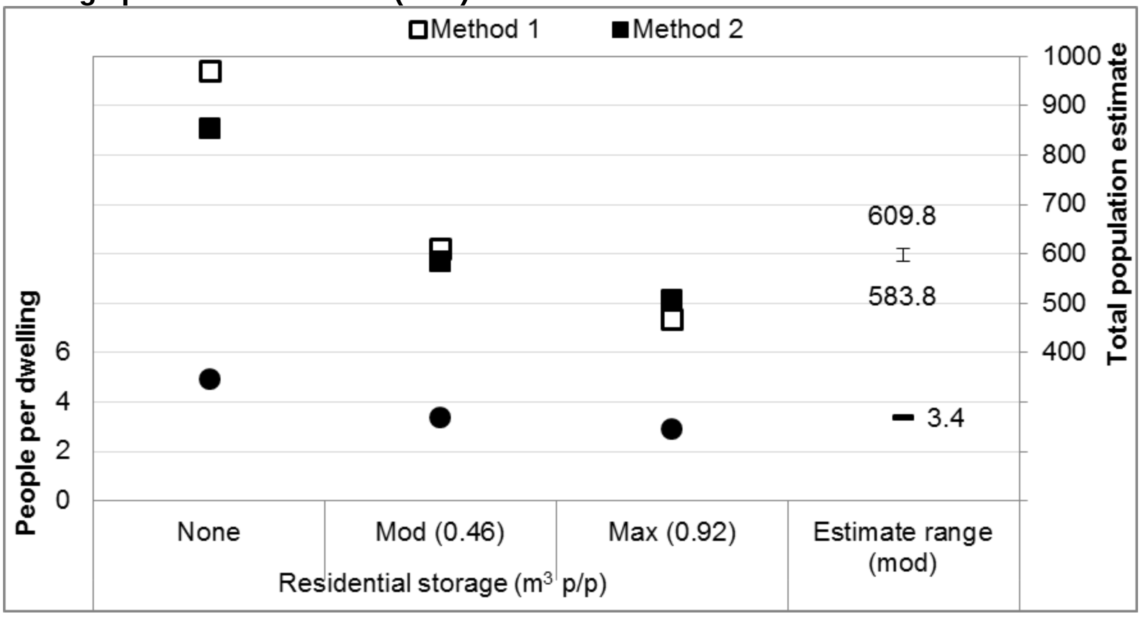
Housing unit method (HUM)

Method 1: Total potential dwelling number				**221.91**
Number of potential dwellings in the assessable area				12
Assessable area (m^2)				486.69
Estimated total site extent (m^2)				9000
Assessable area (proportion)				0.0541
Method 2: Total potential dwelling number				**221.91**
Mean potential residential built area (m^2)				23.25
Potential residential built area (m^2)	*Unit BI*	*11.66*	*Unit CII*	*44.90*
	Unit BIII	*21.89*	*Unit CV*	*26.96*
	Unit BIV	*19.54*	*Unit CVI*	*47.41*
	Unit BV	*5.45*	*Unit CVII*	*26.91*
	Unit BVI	*7.48*	*Unit DI*	*26.22*
	Unit BVIII	*15.21*	*Unit DII*	*25.34*
Total built area estimate (m^2)				8823.58
Assessable area (m^2)				*486.69*
Assessable built area (m^2)				*477.15*
Assessable built area as a proportion of assessable area				*0.9804*
Estimated total site extent (m^2)				*9000*
Residential built area as a proportion of assessable built area				0.5847
Potential residential built area (m^2)				*278.97*
Total potential residential built area (m^2)				5158.87
Method 3: Total potential dwelling number				**221.91**
Potential residential built area as a proportion of assessable area				0.5732
Total number of contemporaneous dwellings (78%)				173.09
Total population estimate based on nuclear family size:	**Minimum**	**3**		**519.26**
	Average	**5.5**		**951.98**
	Maximum	**8**		**1384.70**

Residential area density coefficient (RADC)

Method 1: Total potential residential floor area (m^2)					**3156.07**
Potential residential floor area (m^2)					170.67
Potential residential floor area (m^2)	*Unit BI*	*6.54*	*Unit CII*		*26.47*
	Unit BIII	*13.77*	*Unit CV*		*19.04*
	Unit BIV	*12.55*	*Unit CVI*		*26.66*
	Unit BV	*2.80*	*Unit CVII*		*19.44*
	Unit BVI	*5.55*	*Unit DI*		*15.23*
	Unit BVIII	*11.14*	*Unit DII*		*11.48*
Assessable area (m^2)					486.69
Estimated total site extent (m^2)					9000
Assessable area (proportion)					0.0541
Method 2: Total potential residential floor area (m^2)					**3156.07**
Total built area estimate (m^2)					8823.58
				Assessable area (m^2)	*486.69*
				Assessable built area (m^2)	*477.15*
				Assessable built area as a proportion of assessable area	*0.9804*
				Estimated total site extent (m^2)	*9000*
Potential residential floor area as a proportion of assessable built area					0.3577
				Potential residential floor area (m^2)	*170.67*
Method 3: Total potential residential floor area (m^2)					**3156.07**
Potential residential floor area as a proportion of assessable area					0.3507
Total contemporaneous residential floor area (m^2) (78%)					2461.74
Total population estimate based on RADC (m^2):		**Minimum**	**1.77**		**1390.81**
		Average	**3.3**		**745.98**
		Maximum	**5**		**492.35**

Storage provisions formula (SPF)



			Residential storage provisions (m^3 per person)								
			None *P = 0.3944A – 0.375*			*Moderate (0.46)* *P = 0.2477A + 0.0339*			*Maximum (2 x 0.46)* *P = 0.1903A + 0.3976*		
Method 1: Total population estimate (P) based on total contemporaneous residential floor area (A)											
A	=	2461.74	0.3944 x 2461.74	=	970.91	0.2477 x 2461.74	=	609.77	0.1903 x 2461.74	=	468.47
P	=	?	970.91 - 0.375	=	970.53	609.77 + 0.0339	=	609.81	468.47 + 0.3976	=	468.87
			P	**=**	**970.53**	**P**	**=**	**609.81**	**P**	**=**	**468.87**
Method 2: People per dwelling (P) and total population estimates based on mean residential floor area of complete dwellings (A)											
A	=	13.48	0.3944 x 13.48	=	5.32	0.2477 x 13.48	=	3.34	0.1903 x 13.48	=	2.57
P	=	?	5.32 - 0.375	=	4.94	3.34 + 0.0339	=	3.37	2.57 + 0.3976	=	2.92
			P	**=**	**4.94**	**P**	**=**	**3.37**	**P**	**=**	**2.92**
			Total number of contemporaneous dwellings								*173.09*
		Total population			**855.31**			**583.81**			**506.20**
Mean total population					**912.92**			**596.81**			**487.53**

Naroll's (1962) AGF1

Summary of estimates based on:	**Naroll's (1962) formula**			**Archaeological evidence**			
	SPF population estimate based on amount *of storage:*				*SPF population estimate based on* amount *of storage:*		
	None (912.92)	*Moderate (596.81)*	*Maximum (487.53)*		*None (912.92)*	*Moderate (596.81)*	*Maximum (487.53)*
Total built floor area (m^2)	6745.25	4715.99	3977.64	7834.43			
Built floor area per person (m^2)	7.39	7.90	8.16		8.58	13.13	16.07
RADC (m^2 per person)	2.98	3.18	3.29		2.70	4.12	5.05
Initial growth index	25.20	36.05	42.74				

Data required		
SPF population estimate (P) based on amount of storage:	None	912.92
	Moderate	596.81
	Maximum	487.53
Residential floor area as a proportion of built floor area (%)		40.28
Total built floor area (m^2) (A)		*7834.43*
Built floor area in assessable area (m^2)		*423.66*
Proportion of site assessable (%)		*5.41*
Total residential floor area (m^2) (RADC method)		*3156.07*
Built floor area per person (m^2) derived from SPF population estimates and total built floor area based on amount of storage:	None	8.58
	Moderate	13.13
	Maximum	16.07
RADC derived from SPF population estimates and total contemporaneous residential floor area based on amount of storage:	None	2.70
	Moderate	4.12
	Maximum	5.05
Total contemporaneous residential floor area (m^2) (RADC method)		2461.74

$A = a \times P^b$							
Amount of storage:	*None*	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 912.92^{0.84195}$**		
		P	=	912.92	$912.92^{0.84195}$	=	310.84
		a	=	21.7	21.7 x 310.84	=	6745.25
		b	=	0.84195	**A**	**=**	**6745.25**
		Built floor area per person (m^2)					**7.39**
		RADC (m^2 per person)					**2.98**
					Residential floor area as a proportion of built floor area		*40.28*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	7834.43	**$7834.43 = a \times 912.92^{0.84195}$**		
		P	=	912.92	$912.92^{0.84195}$	=	310.84
		a	=	?	7834.43/310.84	=	25.20
		b	=	0.84195	***a***	**=**	**25.20**
	Moderate	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 596.81^{0.84195}$**		
		P	=	596.81	$596.81^{0.84195}$	=	217.33
		a	=	21.7	21.7 x 217.33	=	4715.99
		b	=	0.84195	**A**	**=**	**4715.99**
		Built floor area per person (m^2)					**7.90**
		RADC (m^2 per person)					**3.18**
					Residential floor area as a proportion of built floor area		*40.28*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	7834.43	**$7834.43 = a \times 596.81^{0.84195}$**		
		P	=	596.81	$596.81^{0.84195}$	=	217.33
		a	=	?	7834.43/217.33	=	36.05
		b	=	0.84195	***a***	**=**	**36.05**
	Maximum	**Method 1: Total built floor area (m^2) (A), built floor area per person and RADC**					
		A	=	?	**$A = 21.7 \times 487.53^{0.84195}$**		
		P	=	487.53	$487.53^{0.84195}$	=	183.30
		a	=	21.7	21.7 x 183.3	=	3977.64
		b	=	0.84195	**A**	**=**	**3977.64**
		Built floor area per person (m^2)					**8.16**
		RADC (m^2 per person)					**3.29**
					Residential floor area as a proportion of built floor area		*40.28*
		Method 2: Re-calculated initial growth index (*a*)					
		A	=	7834.43	**$7834.43 = a \times 487.53^{0.84195}$**		
		P	=	487.53	$487.53^{0.84195}$	=	183.30
		a	=	?	7834.43/183.3	=	42.74
		b	=	0.84195	***a***	**=**	**42.74**

Wiessner's (1974) AGF2

Data required		
Total site extent (m^2) (A)		13500
SPF population estimate (P) based on amount of storage:	None	912.92
	Moderate	596.81
	Maximum	487.53

Amount of storage:					$A = a \times P^b$		
None	**Open settlements**				**$13500 = a \times 912.92^2$**		
	A	=	13500				
	P	=	912.92	912.92^2		=	833431.13
	a	=	?	13500/833431.13		=	0.02
	b	=	2	***a***		**=**	**0.02**
	Village settlements				**$13500 = a \times 912.92^1$**		
	A	=	13500				
	P	=	912.92	912.92^1		=	912.92
	a	=	?	13500/912.92		=	14.8
	b	=	1	***a***		**=**	**14.79**
	Urban settlements				**$13500 = a \times 912.92^{0.6667}$**		
	A	=	13500				
	P	=	912.92	$912.92^{0.6667}$		=	94.13
	a	=	?	13500/94.13		=	143.42
	b	=	0.6667	***a***		**=**	**143.42**
Moderate	**Open settlements**				**$13500 = a \times 596.81^2$**		
	A	=	13500				
	P	=	596.81	596.81^2		=	356177.95
	a	=	?	13500/356177.95		=	0.04
	b	=	2	***a***		**=**	**0.04**
	Village settlements				**$13500 = a \times 596.81^1$**		
	A	=	13500				
	P	=	596.81	596.81^1		=	596.81
	a	=	?	13500/596.81		=	22.6
	b	=	1	***a***		**=**	**22.62**
	Urban settlements				**$13500 = a \times 596.81^{0.6667}$**		
	A	=	13500				
	P	=	596.81	$596.81^{0.6667}$		=	70.90
	a	=	?	13500/70.9		=	190.41
	b	=	0.6667	***a***		**=**	**190.41**
Maximum	**Open settlements**				**$13500 = a \times 487.53^2$**		
	A	=	13500				
	P	=	487.53	487.53^2		=	237689.73
	a	=	?	13500/237689.73		=	0.06
	b	=	2	***a***		**=**	**0.06**
	Village settlements				**$13500 = a \times 487.53^1$**		
	A	=	13500				
	P	=	487.53	487.53^1		=	487.53
	a	=	?	13500/487.53		=	27.7
	b	=	1	***a***		**=**	**27.69**
	Urban settlements				**$13500 = a \times 487.53^{0.6667}$**		
	A	=	13500				
	P	=	487.53	$487.53^{0.6667}$		=	61.96
	a	=	?	13500/61.96		=	217.89
	b	=	0.6667	***a***		**=**	**217.89**

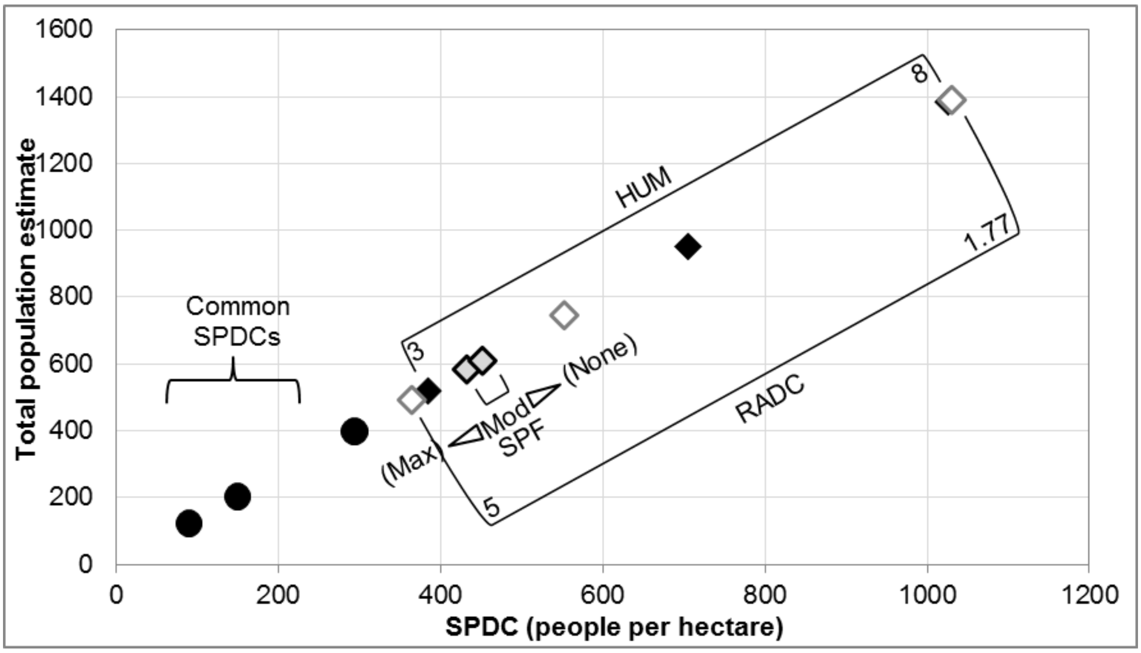
Initial growth indices			
Settlement type	*SPF population estimate based on amount of storage:*		
	None (912.92)	*Moderate (596.81)*	*Maximum (487.53)*
Open	0.02	0.04	0.06
Village	14.79	22.62	27.69
Urban	143.42	190.41	217.89

Settlement population density coefficient (SPDC)

Data required	
Total site extent (ha)	1.35
Proportion of site assessable (%)	5.41
Number of contemporaneous dwellings in the assessable area	9.36
Dwellings in assessable area	*12*
Contemporaneity value (%)	*78*

Method 1: Total population based on commonly utilised SPDCs			
	SPDC (people/ha)		
	Minimum	*Average*	*Maximum*
	90	*150*	*294*
Total population	121.5	202.5	396.9
Population in the assessable area	*6.57*	*10.95*	*21.46*
People per dwelling in the assessable area	*0.70*	*1.17*	*2.29*

Method 2: SPDCs based on HUM, RADC and SPF population estimates						
Method	*Total population estimate*			*SPDC (people/ha)*		
	Minimum	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
HUM	519.26	951.98	1384.70	384.64	705.17	1025.70
RADC	492.35	745.98	1390.81	364.70	552.58	1030.23
SPF	583.81	-	609.81	432.45	-	451.71



Appendix C.2: Micro-level estimate database

		Site	Nahal Oren	Gilgal I	Netiv Hagdud	El-Hemmeh (PPNA)
Site Information		Settlement type	1	2	2	1
		Period	PPNA	PPNA	PPNA	PPNA
		Site extent (hectares)	0.05	0.4	0.75	0.1
		Site extent (hectares) used in calculations of population size	-	-	-	-
		Site extent category (hectares)	<0.4	≥0.4	≥0.4	<0.4
		Structural contemporaneity value (%)	80	60	60	75
		Environment	Restricted	Restricted	Unrestricted	Restricted
		Subsistence (H-Hunt; G-Gath; C-Cult; P-Past)	H, G, C	H, G, C	H, G, C	H, G, C
		Dwelling architecture: predominant shape	Curvilinear	Curvilinear	Curvilinear	Curvilinear
		Dwelling architecture: predominant number of storeys	Single	Single	Single	Single
		Dwelling architecture: degree of compartmentalisation	Absent	Present	Present	Absent
		Economy: household economic independence	Limited-Mod	Limited	Limited-Mod	Limited-Mod
		Ritual	Incipient	Incipient	Established	Incipient
		Complexity in community organisation	Evident	Evident	Evident	Unknown
Housing Unit Method	Data	Dwelling count	10	6	6	6
		Assessable area (m^2)	326.36	214.66	533.82	61.49
		Proportion of site assessable (%)	65.27	5.37	7.12	6.15
		Total number of dwellings	15.32	111.8	84.3	97.58
		Mean residential built area (m^2)	15.08	12.5	28.21	4.9
		Assessable built area (m^2)	178.48	110.31	169.23	33.65
		Proportion of built area in assessable area (%)	54.69	51.39	31.7	54.72
		Total built area (m^2)	273.44	2055.53	2377.63	547.24
		Assessable residential built area (m^2)	150.74	75.01	169.23	29.41
		Proportion of residential built area in built area (%)	84.46	68	100	87.41
		Total residential built area (m^2)	230.94	1397.75	2377.63	478.32
		Proportion of residential built area in assessable area (%)	46.19	34.94	31.7	47.83
	Estimates	Total number of contemporaneous dwellings	12.25	67.08	50.58	73.18
		Total population (3 people)	36.74	201.25	151.74	219.55
		Total population (5.5 people)	67.36	368.96	278.18	402.5
		Total population (8 people)	97.98	536.66	404.63	585.46
		Suitable family sizes	3-5.5	All	All	3

Method	Type	Group	Site		Nahal Oren	Gilgal I	Netiv Hagdud	El-Hemmeh (PPNA)
Residential Area Density Coefficient Method	Data		Assessable residential floor area (m^2)		82.67	59.31	127.99	18.64
			Total residential floor area (m^2)		126.65	1105.27	1798.22	303.08
			Proportion of residential floor area in built area (%)		51.79	53.77	75.63	55.38
			Proportion of residential floor area in assessable area (%)		28.32	27.63	23.98	30.31
	Estimates		Total contemporaneous residential floor area (m^2)		113.3	663.16	1078.93	227.31
			Total population (1.77 m^2 per person)		64.01	374.67	609.57	128.42
			Total population (3.3 m^2 per person)		34.33	200.96	326.95	68.88
			Total population (5 m^2 per person)		22.66	132.63	215.79	45.46
			Suitable RADCs		All	All	All	All
Storage Provisions Formulae	Data		Total contemporaneous residential floor area (m^2)		113.3	663.16	1078.93	227.31
			Mean residential floor area of complete dwellings (m^2)		9.6	12.77	21.33	4.83
			Total number of contemporaneous dwellings		12.25	67.08	50.58	73.18
			Probable amount of interior residential storage		None-max	None-max	Mod-max	None-max
	Estimates	Total population (SPF1 and 2)	No storage (min)		41.79	261.18	406.54	89.28
			No storage (max)		44.31	312.69	425.16	111.96
			0.46^3 storage per person (min)		28.1	164.3	267.29	56.34
			0.46^3 storage per person (max)		29.54	214.46	268.95	90.03
			2 x 0.46^3 storage per person (min)		21.96	126.6	205.72	43.65
			2 x 0.46^3 storage per person (max)		26.78	187.12	223.48	93.56
		People per dwelling (SPF2)	No storage		3.41	4.66	8.04	1.53
			0.46^3 storage per person		2.41	3.2	5.32	1.23
			2 x 0.46^3 storage per person		2.19	2.79	4.42	1.28
Allometric Growth Formulae		Data	Total built floor area (m^2)		163.78	1599.44	1798.22	345.75
			Proportion of residential floor area in built floor area (%)		86.47	69.1	100	87.66
		Naroll (AGF1)	Total built floor area (m^2)	No storage	515.44	2545.59	3479.13	1053.46
				Mod storage	367.68	1794.14	2404.3	805.77
				Max storage	319.24	1530.95	1993.32	763.1
			Built floor area per person (m^2)	No storage	11.97	8.87	8.37	10.47
				Mod storage	12.76	9.47	8.97	11.01
				Max storage	13.1	9.76	9.29	11.12
			RADC (m^2 residential floor area per person)	No storage	10.35	6.13	8.37	9.18
				Mod storage	11.03	6.55	8.97	9.65
				Max storage	11.33	6.74	9.29	9.75
			Re-calculated initial growth index	No storage	6.9	13.63	11.22	7.12
				Mod storage	9.67	19.35	16.23	9.32
				Max storage	11.13	22.67	19.58	9.83

		Site		Nahal Oren	Gilgal I	Netiv Hagdud	El-Hemmeh (PPNA)
Allometric Growth Formulae	Wiessner (AGF2 initial growth indices)	Predominant settlement type/s		Open/village	Open/village	Open/village	Open/village
		Open	No storage	0.27	0.05	0.04	0.1
			Mod storage	0.6	0.11	0.1	0.19
			Max storage	0.84	0.16	0.16	0.21
		Village	No storage	11.61	13.9	18.04	9.94
			Mod storage	17.35	21.12	27.97	13.66
			Max storage	20.52	25.5	34.95	14.58
		Urban	No storage	40.7	91.93	134.59	46.22
			Mod storage	53.18	121.27	180.34	57.15
			Max storage	59.48	137.51	209.2	59.66
Settlement Population Density Coefficient Method	Total population based on:		90 people/ha	4.5	36	67.5	9
			150 people/ha	7.5	60	112.5	15
			294 people/ha	14.7	117.6	220.5	29.4
	Population in assessable area:		90 people/ha	2.94	1.93	4.8	0.55
			150 people/ha	4.9	3.22	8.01	0.92
			294 people/ha	9.59	6.32	15.69	1.81
	Contemporaneous dwellings in assessable area			8	3.6	3.6	4.5
	People per dwelling in assessable area:		90 people/ha	0.37	0.54	1.33	0.12
			150 people/ha	0.61	0.9	2.22	0.2
			294 people/ha	1.2	1.75	4.36	0.4

		Site	Nahal Oren	Gilgal I	Netiv Hagdud	El-Hemmeh (PPNA)
Final Estimates	Total population	HUM	36.74-67.36	201.25-536.66	151.74-404.63	219.55
		RADC	22.66-64.01	132.63-374.67	215.79-609.57	45.46-128.42
		SPF	24.37-43.05	156.86-286.93	214.6-268.12	68.62-100.62
		SPDC	4.5-14.7	36-117.60	67.5-220.5	9-29.4
	People per dwelling	HUM	3-5.5	3-8	3-8	3
		RADC	1.85-5.23	1.98-5.59	4.27-12.05	0.62-1.75
		SPF1	1.99-3.51	2.34-4.28	4.24-5.3	0.94-1.37
		SPF2	2.19-3.41	2.79-4.66	4.42-5.32	1.23-1.53
		SPDC	0.37-1.2	0.54-1.75	1.33-4.36	0.12-0.4
	Residential floor area density	HUM	1.68-3.08	1.24-3.30	2.67-7.11	1.04
	coefficient	RADC	1.77-5	1.77-5.00	1.77-5.00	1.77-5.00
		SPF	2.63-4.65	2.31-4.23	4.02-5.03	2.26-3.31
	(m^2 per person)	AGF1	10.35-11.3	6.13-6.74	8.97-9.29	8.19-8.72
		SPDC	7.71-25.18	5.64-18.42	4.89-15.98	7.73-25.26
	Settlement population density	HUM	734.8-1347.2	503.13-1341.65	202.32-539.51	2195.48
	coefficient	RADC	453.19-1280.21	331.58-936.67	287.71-812.75	454.62-1284.23
		SPF	487.39-860.98	392.14-717.33	286.13-357.49	686.06-1006.19
	(people per hectare)	SPDC	90-294	90-294	90-294	90-294
	Mean residential built area: complete dwellings (m^2)		16.34	15.95	28.21	7.56
Final Area Proportions	Built floor area in:	site area (%)	32.76	40.01	23.98	34.57
		assessable built area (%)	59.89	77.86	75.63	63.18
	Contemporaneous:	built area in site area (%)	43.75	30.83	19.02	41.04
		residential built area in assessable area (%)	36.95	20.97	19.02	35.87
		built floor area in assessable area (%)	26.2	24.01	14.39	25.93
		residential floor area in assessable area (%)	22.66	16.58	14.39	22.73
	Residential floor area in built floor area (%)		86.47	69.1	100	87.66
	Built area in site area (structural density) (%)		54.69	51.39	31.70	54.72

		Site	Shkārat Msaied	Ghwair I	Wadi Hamarash I	‘Ain Abu Nekheileh
Site Information		Settlement type	1	4	3	1
		Period	MPPNB	MPPNB	MPPNB	MPPNB
		Site extent (hectares)	0.2	1.2-1.45	0.5	0.12
		Site extent (hectares) used in calculations of population size	-	1	-	-
		Site extent category (hectares)	<0.4	0.6-6.9	≤0.5	<0.4
		Structural contemporaneity value (%)	80	77.78	78	65
		Environment	Restricted	Restricted	Restricted	Restricted
		Subsistence (H-Hunt; G-Gath; C-Cult; P-Past)	H, G, C, P	H, G, C, P	H, G, C, P	H, G, C, P
		Dwelling architecture: predominant shape	Curvilinear	Rectilinear	Rectilinear	Curvilinear
		Dwelling architecture: predominant number of storeys	Single	Multiple	Multiple	Single
		Dwelling architecture: degree of compartmentalisation	Present	Present	Present	Present
		Economy: household economic independence	Limited-Mod	High	High	Moderate
		Ritual	Established	Established	Established	Unknown
		Complexity in community organisation	Evident	Well-established	Well-established	Evident
Housing Unit Method	Data	Dwelling count	13	6	16	9
		Assessable area (m^2)	679.91	440.75	1249.49	135.3
		Proportion of site assessable (%)	34	4.41	24.99	11.28
		Total number of dwellings	38.24	136.13	64.03	79.82
		Mean residential built area (m^2)	24.01	24.04	17.17	12.62
		Assessable built area (m^2)	395.23	281.67	789.16	129.16
		Proportion of built area in assessable area (%)	58.13	63.91	63.16	95.46
		Total built area (m^2)	1162.6	6390.7	3157.95	1145.54
		Assessable residential built area (m^2)	312.15	144.27	274.65	113.59
		Proportion of residential built area in built area (%)	78.98	51.22	34.8	87.94
		Total residential built area (m^2)	918.22	3273.2	1099.06	1007.41
		Proportion of residential built area in assessable area (%)	45.91	32.73	21.98	83.95
	Estimates	Total number of contemporaneous dwellings	30.59	105.88	49.94	51.88
		Total population (3 people)	91.78	317.65	149.82	155.65
		Total population (5.5 people)	168.26	582.36	274.67	285.37
		Total population (8 people)	244.74	847.07	399.53	415.08
		Suitable family sizes	All	All	All	3-5.5

			Site		Shkārat Msaied	Ghwair I	Wadi Hamarash I	‘Ain Abu Nekheileh
Residential Area Density Coefficient Method		Data	Assessable residential floor area (m^2)		158.85	90.85	181.52	66.88
			Total residential floor area (m^2)		467.27	2061.31	726.38	593.16
			Proportion of residential floor area in built area (%)		40.19	32.25	23	51.78
			Proportion of residential floor area in assessable area (%)		23.36	20.61	14.53	49.43
		Estimates	Total contemporaneous residential floor area (m^2)		373.81	1603.29	566.58	385.56
			Total population (1.77 m^2 per person)		211.19	905.81	320.1	217.83
			Total population (3.3 m^2 per person)		113.28	485.84	171.69	116.83
			Total population (5 m^2 per person)		74.76	320.66	113.32	77.11
			Suitable RADCs		All	All	All	All
Storage Provisions Formulae	Data		Total contemporaneous residential floor area (m^2)		373.81	1603.29	566.58	385.56
			Mean residential floor area of complete dwellings (m^2)		13.46	15.14	12.22	7.98
			Total number of contemporaneous dwellings		30.59	105.88	49.94	51.88
			Probable amount of interior residential storage		None-max	None-mod	None-mod	None-max
	Estimates	Total population (SPF1 and 2)	No storage (min)		147.06	592.54	221.97	143.84
			No storage (max)		150.92	631.96	223.08	151.69
			0.46^3 storage per person (min)		92.63	397.17	140.38	95.54
			0.46^3 storage per person (max)		103.03	400.67	152.86	104.32
			2 x 0.46^3 storage per person (min)		71.53	305.5	108.22	73.77
			2 x 0.46^3 storage per person (max)		89.35	343.11	134.08	97.43
		People per dwelling (SPF2)	No storage		4.93	5.6	4.44	2.77
			0.46^3 storage per person		3.37	3.78	3.06	2.01
			2 x 0.46^3 storage per person		2.92	3.24	2.68	1.88
Allometric Growth Formulae		Data	Total built floor area (m^2)		589.32	3869.99	1828.16	647.63
			Proportion of residential floor area in built floor area (%)		79.29	53.26	39.73	91.59
		Naroll (AGF1)	Total built floor area (m^2)	No storage	1466	4818.55	2055.1	1455.89
				Mod storage	1028.8	3359.5	1446.36	1047.35
				Max storage	872.51	2822.01	1231.7	919.42
			Built floor area per person (m^2)	No storage	9.84	7.87	9.24	9.85
				Mod storage	10.52	8.42	9.86	10.48
				Max storage	10.85	8.7	10.17	10.74
			RADC (m^2 residential floor area per person)	No storage	7.8	4.19	3.67	9.02
				Mod storage	8.34	4.19	3.92	9.6
				Max storage	8.6	4.63	4.04	9.84
			Re-calculated initial growth index	No storage	8.72	17.43	19.3	9.65
				Mod storage	12.43	25	27.43	13.42
				Max storage	14.66	29.76	32.21	15.29

		Site		Shkārat Msaied	Ghwair I	Wadi Hamarash I	‘Ain Abu Nekheileh
Allometric Growth Formulae	Wiessner (AGF2 initial growth indices)	Predominant settlement type/s		Open/village	Village-urban	Village-urban	Village
		Open	No storage	0.09	0.04	0.1	0.05
			Mod storage	0.21	0.08	0.23	0.12
			Max storage	0.31	0.13	0.34	0.16
		Village	No storage	13.42	21.64	22.47	8.12
			Mod storage	20.44	33.21	34.1	12.01
			Max storage	24.86	40.86	41.27	14.02
		Urban	No storage	71.15	183.73	136.14	42.93
			Mod storage	94.19	244.46	179.79	55.72
			Max storage	107.31	280.65	204.19	61.77
Settlement Population Density Coefficient Method	Total population based on:		90 people/ha	18	119.25	45	10.8
			150 people/ha	30	198.75	75	18
			294 people/ha	58.8	389.55	147	35.28
	Population in assessable area:		90 people/ha	6.12	5.26	11.25	1.22
			150 people/ha	10.2	8.76	18.74	2.03
			294 people/ha	19.99	17.18	36.73	3.98
	Contemporaneous dwellings in assessable area			10.4	4.67	16	5.85
	People per dwelling in assessable area:		90 people/ha	0.59	1.13	0.9	0.21
			150 people/ha	0.98	1.88	1.5	0.35
			294 people/ha	1.92	3.68	2.94	0.68

		Site	Shkārat Msaied	Ghwair I	Wadi Hamarash I	‘Ain Abu Nekheileh
Final Estimates	Total population	HUM	91.78-244.74	317.65-847.07	149.82-399.53	155.65-285.37
		RADC	74.76-211.19	320.66-905.81	113.32-320.10	77.11-217.83
		SPF	80.44-148.99	398.92-612.25	146.62-222.52	85.6-147.76
		SPDC	18-58.8	119.25-389.55	45-147	10.8-35.28
	People per dwelling	HUM	3-8	3-8	3-8	3-5.5
		RADC	2.44-6.9	3.03-8.55	2.27-6.41	1.49-4.2
		SPF1	2.63-4.87	3.77-5.78	2.94-4.46	1.65-2.85
		SPF2	2.92-4.93	3.78-5.6	3.06-4.44	1.88-2.77
		SPDC	0.59-1.92	1.13-3.68	0.9-2.94	0.21-0.68
	Residential floor area density	HUM	1.53-4.07	1.89-5.05	1.42-3.78	1.35-2.48
	coefficient	RADC	1.77-5	1.77-5	1.77-5.00	1.77-5
		SPF	2.51-4.65	2.62-4.02	2.55-3.86	2.61-4.5
	(m^2 per person)	AGF1	7.8-8.6	4.19-4.49	3.67-3.92	9.02-9.84
		SPDC	6.36-20.77	4.12-13.44	3.85-12.59	10.93-35.7
	Settlement population density	HUM	458.88-1223.69	317.65-847.07	299.64-799.05	1297.12-2378.05
	coefficient	RADC	373.81-1055.97	320.66-905.81	226.63-640.2	642.59-1815.23
		SPF	402.2-744.94	398.92-612.25	293.23-445.05	713.34-1231.37
	(people per hectare)	SPDC	90-294	90-294	90-294	90-294
	Mean residential built area: complete dwellings (m^2)		26.32	24.04	14.47	14.29
Final Area Proportions	Built floor area in:	site area (%)	29.47	29.21	36.56	53.97
		assessable built area (%)	50.7	60.56	57.89	56.53
	Contemporaneous:	built area in site area (%)	46.5	37.51	49.26	62.05
		residential built area in assessable area (%)	36.73	19.21	17.15	54.57
		built floor area in assessable area (%)	23.58	22.72	28.52	35.08
		residential floor area in assessable area (%)	18.69	12.1	11.33	32.13
	Residential floor area in built floor area (%)		79.29	53.26	39.73	91.59
	Built area in site area (structural density) (%)		59.13	48.23	63.16	95.46

		Site	El-Hemmeh (LPPNB)	Basta	Ba'ja
Site Information		Settlement type	4	5	4
		Period	LPPNB	LPPNB	LPPNB
		Site extent (hectares)	1	12-14	1.2-1.5
		Site extent (hectares) used in calculations of population size	0.8	10	0.9
		Site extent category (hectares)	0.6-6	≥7	0.6-6
		Structural contemporaneity value (%)	78	60.47	78
		Environment	Restricted	Unrestricted	Restricted
		Subsistence (H-Hunt; G-Gath; C-Cult; P-Past)	H, G, C, P	H, G, C, P	H, G, C, P
		Dwelling architecture: predominant shape	Rectilinear	Rectilinear	Rectilinear
		Dwelling architecture: predominant number of storeys	Multiple	Single/Multiple	Multiple
		Dwelling architecture: degree of compartmentalisation	Present	Present	Present
		Economy: household economic independence	High	High	High
		Ritual	Established	Well-established	Established
		Complexity in community organisation	Well-established	Well-established	Well-established
Housing Unit Method	Data	Dwelling count	4	6	12
		Assessable area (m^2)	101.38	302.51	486.69
		Proportion of site assessable (%)	1.27	0.3	5.41
		Total number of dwellings	315.64	1983.41	221.91
		Mean residential built area (m^2)	13.23	27.14	23.25
		Assessable built area (m^2)	101.24	302.51	477.15
		Proportion of built area in assessable area (%)	99.86	100	98.04
		Total built area (m^2)	7988.95	100000	8823.58
		Assessable residential built area (m^2)	52.91	162.81	278.97
		Proportion of residential built area in built area (%)	52.26	53.82	58.47
		Total residential built area (m^2)	4175.18	53819.71	5158.87
		Proportion of residential built area in assessable area (%)	52.19	53.82	57.32
	Estimates	Total number of contemporaneous dwellings	246.2	1199.37	173.09
		Total population (3 people)	738.61	3598.1	519.26
		Total population (5.5 people)	1354.11	6596.51	951.98
		Total population (8 people)	1969.62	9594.92	1384.7
		Suitable family sizes	3-5.5	All	All

Method	Type	Estimate	Site	Storage	El-Hemmeh (LPPNB)	Basta	Ba'ja
Residential Area Density Coefficient Method	Data		Assessable residential floor area (m^2)		34.66	114.94	170.67
			Total residential floor area (m^2)		2734.66	38004.63	3156.07
			Proportion of residential floor area in built area (%)		34.23	38	35.77
			Proportion of residential floor area in assessable area (%)		34.18	38	35.07
	Estimates		Total contemporaneous residential floor area (m^2)		2133.04	22981.4	2461.74
			Total population (1.77 m^2 per person)		1205.11	12983.84	1390.81
			Total population (3.3 m^2 per person)		646.37	6964.06	745.98
			Total population (5 m^2 per person)		426.61	4596.28	492.35
			Suitable RADCs		All	All	All
Storage Provisions Formulae	Data		Total contemporaneous residential floor area (m^2)		2133.04	22981.4	2461.74
			Mean residential floor area of complete dwellings (m^2)		8.66	26.3	13.48
			Total number of contemporaneous dwellings		246.2	1199.37	173.09
			Probable amount of interior residential storage		None-mod	Mod	Mod
	Estimates	Total population (SPF1 and 2)	No storage (min)		748.58	9063.49	855.31
			No storage (max)		840.89	11990.92	970.53
			0.46^3 storage per person (min)		528.39	5692.53	596.81
			0.46^3 storage per person (max)		536.47	7853.94	609.81
			2 x 0.46^3 storage per person (min)		406.31	4373.76	468.87
			2 x 0.46^3 storage per person (max)		494.2	6433.62	506.2
		People per dwelling (SPF2)	No storage		3.04	10	4.94
			0.46^3 storage per person		2.18	6.55	3.37
			2 x 0.46^3 storage per person		2.01	5.36	2.92
Allometric Growth Formulae	Data		Total built floor area (m^2)		6111.66	69733.23	7834.43
			Proportion of residential floor area in built floor area (%)		44.74	54.5	40.28
	Naroll (AGF1)		Total built floor area (m^2)	No storage	6002.09	52850.14	6745.25
				Mod storage	4283.86	36459.46	4715.99
				Max storage	3719.99	30143.83	3977.64
			Built floor area per person (m^2)	No storage	7.55	5.02	7.39
				Mod storage	8.05	5.38	7.9
				Max storage	8.26	5.58	8.16
			RADC (m^2 residential floor area per person)	No storage	3.38	2.74	2.98
				Mod storage	3.6	2.93	3.18
				Max storage	3.7	3.04	3.29
			Re-calculated initial growth index	No storage	22.1	28.63	25.2
				Mod storage	30.96	41.51	36.05
				Max storage	35.65	50.2	42.74

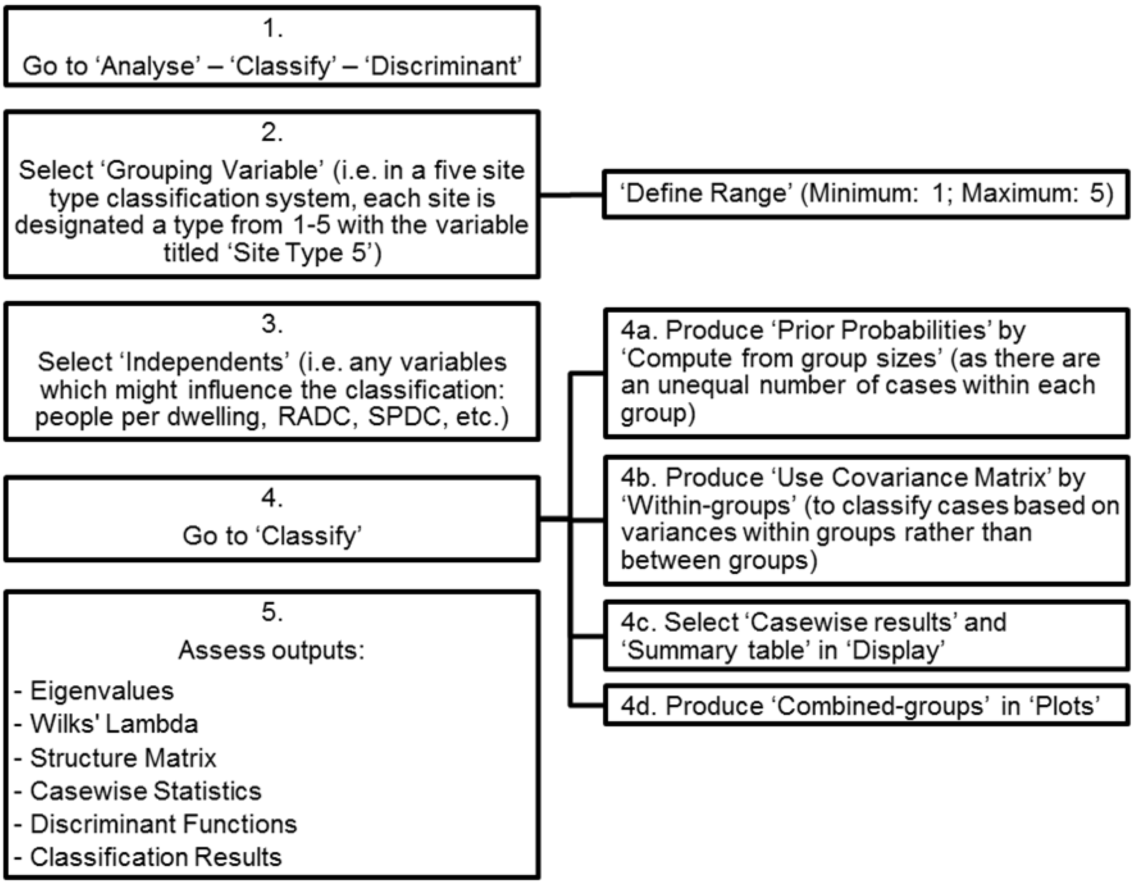
		Site		El-Hemmeh (LPPNB)	Basta	Ba'ja
Allometric Growth Formulae	Wiessner (AGF2 initial growth indices)	Predominant settlement type/s		Village-urban	Village-urban	Village-urban
		Open	No storage	0.02	0.00	0.02
			Mod storage	0.04	0.00	0.04
			Max storage	0.05	0.00	0.06
		Village	No storage	12.58	12.35	14.79
			Mod storage	18.78	19.19	22.62
			Max storage	22.21	24.06	27.69
		Urban	No storage	116.53	270.56	143.42
			Mod storage	152.20	363.04	190.41
			Max storage	170.19	422.04	217.89
Settlement Population Density Coefficient Method	Total population based on:		90 people/ha	90	1170	121.5
			150 people/ha	150	1950	202.5
			294 people/ha	294	3822	396.9
	Population in assessable area:		90 people/ha	1.14	3.54	6.57
			150 people/ha	1.9	5.9	10.95
			294 people/ha	3.73	11.56	21.46
	Contemporaneous dwellings in assessable area			3.12	3.63	9.36
	People per dwelling in assessable area:		90 people/ha	0.37	0.98	0.7
			150 people/ha	0.61	1.63	1.17
			294 people/ha	1.19	3.19	2.29

		Site	El-Hemmeh (LPPNB)	Basta	Ba'ja
Final Estimates	Total population	HUM	738.61-1354.11	3598.1-9594.92	519.26-1384.7
		RADC	426.61-1205.11	4596.28-12983.84	492.35-1390.81
		SPF	532.43-794.74	5692.53-7853.94	583.81-609.81
		SPDC	90-294	1170-3822	121.5-396.9
	People per dwelling	HUM	3-5.5	3-8	3-8
		RADC	1.73-4.89	3.83-10.83	2.84-8.04
		SPF1	2.16-3.23	4.75-6.55	3.37-3.52
		SPF2	2.18-3.04	6.55	3.37
		SPDC	0.37-1.19	0.98-3.19	0.7-2.29
	Residential area density coefficient	HUM	1.58-2.89	2.4-6.39	1.78-4.74
		RADC	1.77-5.00	1.77-5.00	1.77-5.00
		SPF	2.68-4.01	2.93-4.04	4.04-4.22
		AGF1	3.38-3.6	2.87-3.02	3.18
		SPDC	7.26-23.7	6.01-19.64	6.2-20.26
	Settlement population density coefficient	HUM	923.26-1692.64	276.79-738.07	576.96-1538.56
		RADC	533.26-1506.38	353.56-998.76	547.05-1545.35
		SPF	665.54-993.42	437.89-604.15	648.67-677.56
		SPDC	90-294	90-294	90-294
	Mean residential built area: complete dwellings (m^2)		15.32	37.11	23.20
Final Area Proportions	Built floor area in:	site area (%)	61.12	53.64	58.03
		assessable built area (%)	76.5	69.73	88.79
	Contemporaneous:	built area in site area (%)	62.31	46.52	50.98
		residential built area in assessable area (%)	32.57	25.03	29.81
		built floor area in assessable area (%)	47.67	32.44	45.27
		residential floor area in assessable area (%)	21.33	17.68	18.24
	Residential floor area in built floor area (%)		44.74	54.5	40.28
	Built area in site area (structural density) (%)		79.89	76.92	65.36

Appendix D: Statistical tests for micro-level analyses

Discriminant function analysis

Process in SPSS

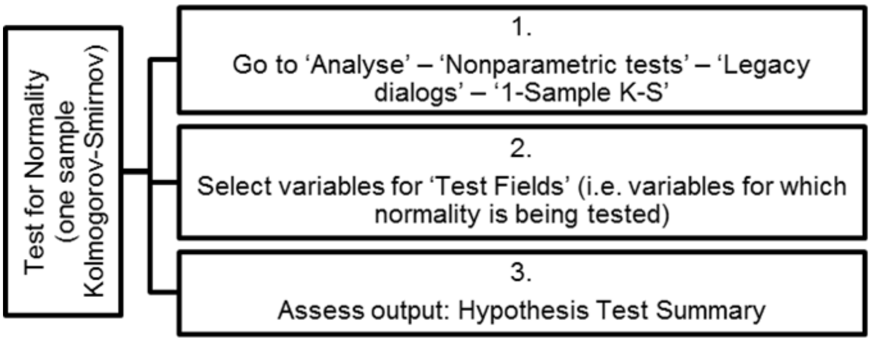


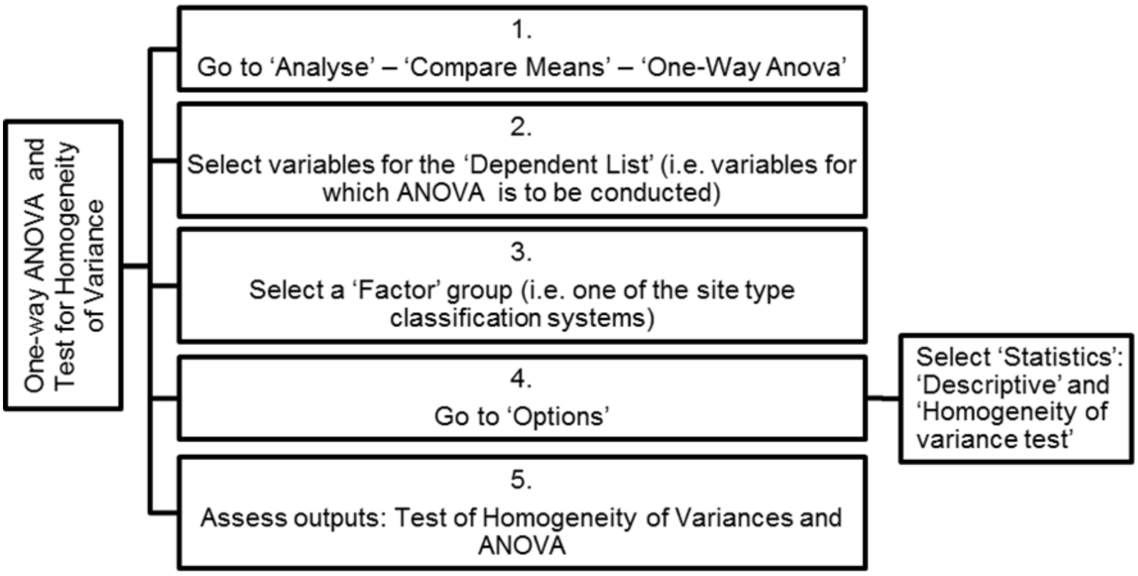
Description of outputs

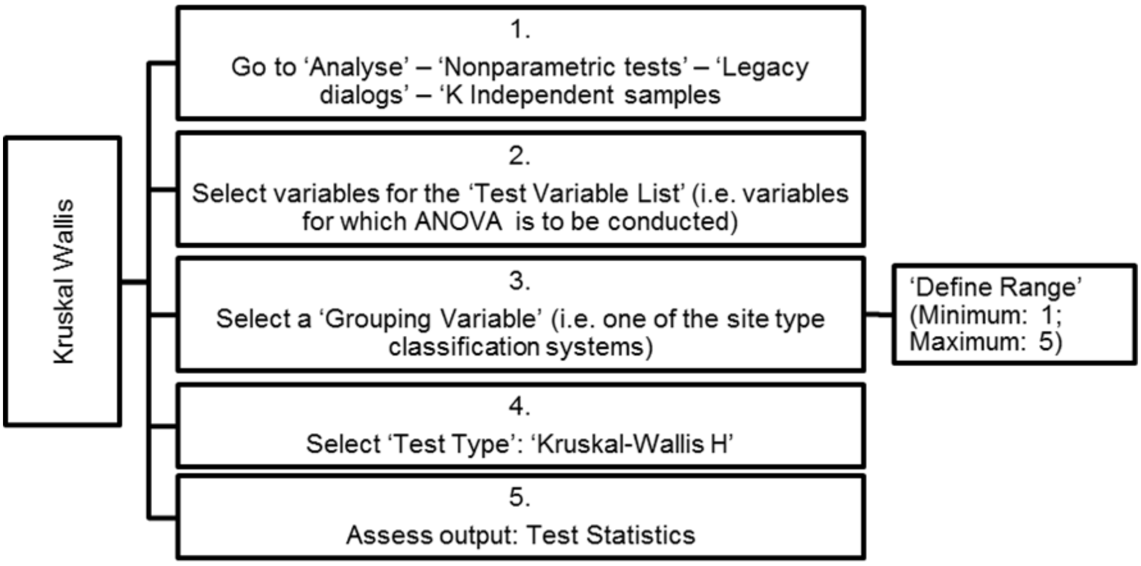
Output	Purpose	Interpretation
Eigenvalues	Indicates the order of importance of discriminant functions (i.e. linear combinations of discriminating variables) for explaining variance.	Functions with the highest Eigenvalues and Canonical Correlations have the greatest impact on variance and classification.
Wilks' Lambda statistics	Indicates which discriminant functions contribute most and least to classification.	Functions with a Wilks' Lambda closest to '0' contribute most to classification. The Chi-square test significance (p) value of $<$ .05 indicates a significant contribution.
Structure matrix	Reveals correlations between each variable and the discriminant function.	Variables with a correlation of 0.3/-0.3 or more are considered important within the function. These are essentially factor loadings of variables within the discriminant functions that indicate which variables contribute most to variances and classification.
Casewise statistics	Displays actual and predicted groups, and provides a Squared Mahalanobis Distance to Centroid (D^2) value (a measure of the distance from the centroid of the group).	Misclassified cases are highlighted in the predicted groups column. A D^2 value closest to '0' reflects a higher probability that the case fits within the predicted group.
Discriminant functions (graph)	Plots cases in relation to group centroids based on the two functions which contribute most to classification.	A visual representation of centroids and D^2 values.
Classification results	Indicates the number and percentage of correctly classified cases.	Comparison of values between groups indicate where cases have been incorrectly classified.

Tests for normality, homogeneity of variance and analysis of variance (ANOVA and Kuskal-Wallis)

Process in SPSS





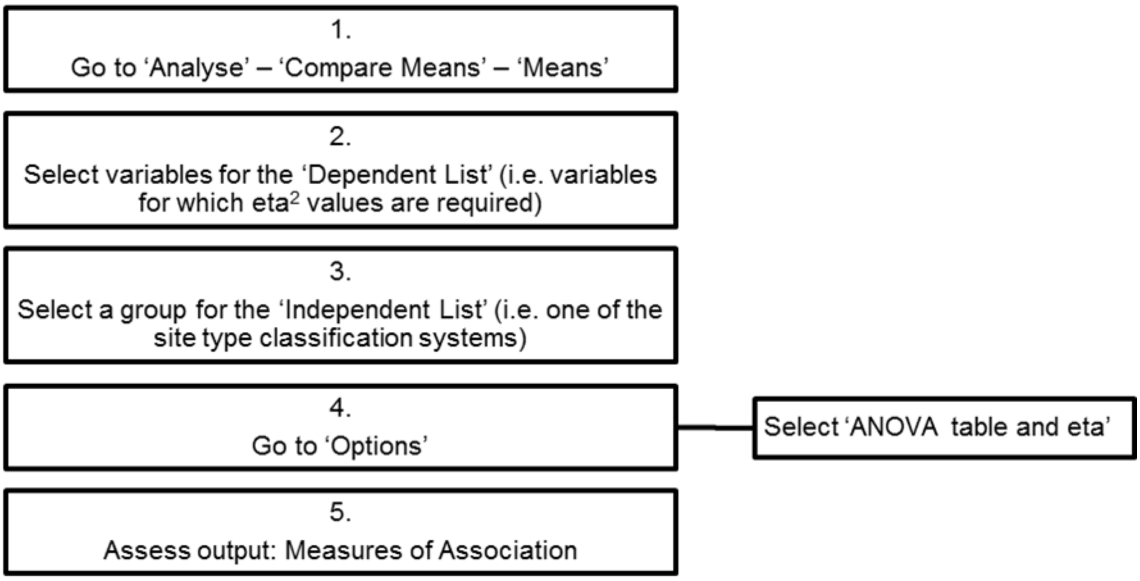


Description of outputs

Output	Purpose	Interpretation
Hypothesis test summary	Identifies whether data is normally distributed.	A significance (*p*) value of > .05 indicates normal distribution.
Test of homogeneity of variance	Identifies whether data displays equal variance between groups.	A significance (*p*) value of > .05 indicates equal variance.
One-way ANOVA	Identifies whether there are significant differences in the mean values of variables between groups (i.e. site type).	A significance (*p*) value of < .05 indicates significant difference.
Kruskal-Wallis test statistics	Identifies whether there are significant differences in the median values of variables between groups (i.e. site type).	A significance (*p*) value of < .05 indicates significant difference.

Effect size (ETA squared/eta^2) test

Process in SPSS



Appendix E.1: The central and southern Levantine PPN village database

ID	Site name	Site type	Period	Predominant architectural form	Site extent (ha)	Latitude	Longitude	Country	References
1	‘Ain Darat	1	PPNA	Curvilinear	0.08	31.512	35.288	Israel	Bar-Yosef 1994; Gopher 1995; Gopher 1996
2	Bir el-Maksur	1	PPNA	Curvilinear	0.20	32.777	35.221	Israel	Malinsky-Buller *et al.* 2009; Malinsky-Buller and Aladjem 2011
3	Borj Barajne	1	PPNA	Curvilinear	0.20[b]	33.820	35.510	Lebanon	Copeland 1991
4	Ein Suhun	1	PPNA	Curvilinear	0.30	32.330	35.370	Palestine	Nadel *et al.* 1999; Sayej 2004
5	El Aoui Safa	1	PPNA	Curvilinear	0.20[b]	33.030	37.150	Syria	Coqueugniot and Anderson 1996
6	El Hemmeh	1	PPNA	Curvilinear	0.10	30.970	35.730	Jordan	Makarewicz and Austin 2006; White and Makarewicz 2012
7	Gesher	1	PPNA	Curvilinear	0.15	32.650	35.510	Israel	Garfinkel 1989; Kuijt and Bar-Yosef 1994
8	Gilgal III	1	PPNA	Curvilinear	0.10	31.990	35.450	Palestine	Noy 1985; Hours 1994; Kuijt and Bar-Yosef 1994
9	Gilgal IV	1	PPNA	Curvilinear	0.10	31.990	35.460	Palestine	Noy 1985; Hours 1994; Kuijt and Bar-Yosef 1994
10	Hatoula	1	PPNA	Curvilinear	0.20	31.780	35.150	Israel	Lechevallier and Ronen 1985; Davis *et al.* 1994
11	Nahal Oren	1	PPNA	Curvilinear	0.05	32.710	34.960	Israel	Flannery 1969; Noy 1973; 1975; Fellner 1995; Byrd 2000
12	Zahrat Adh-Dhra' 2	1	PPNA	Curvilinear	0.20	31.280	35.530	Jordan	Edwards 2002; Sayej 2004
13	Dhra'	2	PPNA	Curvilinear	0.45	31.270	35.580	Jordan	Kuijt 1998
14	Gilgal I	2	PPNA	Curvilinear	0.40	31.990	35.440	Palestine	Noy 1985; Hours 1994; Kuijt and Bar-Yosef 1994
15	Huzuq Musa	2	PPNA	Curvilinear	1.00	32.305	35.501	Palestine	Winter 2005; Zertal 2005; Nadel and Rosenberg 2013
16	Jericho	2	PPNA	Curvilinear	2.50	31.850	35.430	Palestine	Aurenche 1981; Kenyon 1981; Hopf 1983; Hours *et al.* 1994
17	Netiv Hagdud	2	PPNA	Curvilinear	0.75	32.000	35.420	Palestine	Bar-Yosef 1980; Kislev 1997
18	Tell Aswad IA	2	PPNA	Curvilinear	1.00	33.590	36.380	Syria	de Contenson 1979; Moore 1983; Stordeur 2003
19	‘Ain Abu Hudhud	1	EPPNB	Curvilinear[a]	0.20	31.070	35.870	Jordan	Rollefson 1996; Kuijt and Goring-Morris 2002; Sayej 2004
20	Ein Suhun	1	EPPNB	Curvilinear	0.30	32.330	35.370	Palestine	Nadel *et al.* 1999; Sayej 2004
21	El Hemmeh	1	EPPNB	Curvilinear	0.10	30.970	35.730	Jordan	Makarewicz and Austin 2006; White and Makarewicz 2012
22	Motza VI	2	EPPNB	Curvilinear[a]	0.50[b]	31.790	35.170	Israel	Yizhaq *et al.* 2005; Khalaily *et al.* 2007; Kroot 2014
23	Mujahiya	2	EPPNB	Curvilinear	0.50[b]	32.820	35.680	Israel	Gopher 1990; Kuijt and Goring-Morris 2002; Sayej 2004
24	Tell Aswad IB	2	EPPNB	Curvilinear[a]	1.00	33.590	36.380	Syria	de Contenson 1979; Moore 1983; Stordeur 2003
25	Horvat Galil	4	EPPNB	Rectilinear[a]	1.00	32.950	35.320	Israel	Gopher 1997; Edwards 2004; Sayej 2004
26	Tell Qarassa	4	EPPNB	Rectilinear[a]	1.00[b]	32.798	36.278	Syria	Ibanez *et al.* 2010
27	Mishmar Ha’emeq	-	EPPNB	Unknown	1.00	32.609	35.142	Israel	Barzilai and Getzov 2008
28	Adh-Dhaman I	1	MPPNB	Curvilinear	0.20	30.270	35.400	Jordan	Moore 1978; Gebel 1988
29	‘Ain Abu Nekheileh	1	MPPNB	Curvilinear[a]	0.12	29.550	35.400	Jordan	Henry *et al.* 2002; Henry *et al.* 2003
30	Beidha	1	MPPNB	Curvilinear[a]	0.20	30.370	35.450	Jordan	Helbaek 1966; Aurenche 1981; Byrd 1989; 1994; Colledge 2001
31	Jebel Arqa	1	MPPNB	Curvilinear	0.20	29.745	35.351	Jordan	Fabiano *et al.* 2004; Wright 2008
32	Jebel Rabigh	1	MPPNB	Curvilinear	0.06	29.950	35.517	Jordan	Fabiano *et al.* 2004; Wright 2008
33	Jebel Ragref	1	MPPNB	Curvilinear	0.15[b]	29.540	35.390	Jordan	Fabiano *et al.* 2004; Wright 2008
34	Jebel Salaqa	1	MPPNB	Curvilinear	0.10	29.800	35.400	Jordan	Fabiano *et al.* 2004; Wright 2008

ID	Site name	Site type	Period	Predominant architectural form	Site extent (ha)	Latitude	Longitude	Country	References
35	Shkārat Msaied	1	MPPNB	Curvilinear	0.20[b]	30.450	35.450	Jordan	Gebel 1988; Jensen 2004; Kinzel 2004; Hermansen *et al.* 2006
36	Tell Eli IV	2	MPPNB	Curvilinear[a]	2.00[b]	32.680	35.550	Israel	de Vaux 1976
37	Abu Gosh	3	MPPNB	Rectilinear	0.25	31.800	35.120	Israel	Lechevallier 1978; Khalaily *et al.* 2003; Kroot 2014
38	Wadi Hamarash I	3	MPPNB	Rectilinear	0.50	31.010	35.540	Jordan	Politis *et al.* 2009; Sampson 2012; Kroot 2014
39	‘Ail IV	4	MPPNB	Rectilinear	1.00[b]	29.967	35.367	Jordan	Gebel 2004b; 2008; Asouti 2006; Purschwitz 2013
40	'Ain Ghazal	4	MPPNB	Rectilinear	4.00	31.988	35.976	Jordan	Banning 1984; Rollefson 1986; 1992; 2000; Campbell 2009
41	Beisamoun	4	MPPNB	Rectilinear	5.00[b]	33.120	35.570	Israel	Lechevallier 1978
42	Ghwair I	4	MPPNB	Rectilinear	1.325	30.600	35.520	Jordan	Simmons and Najjar 1998
43	Horvat Galil	4	MPPNB	Rectilinear[a]	2.50	32.950	35.320	Israel	Gopher 1997; Edwards 2004; Sayej 2004
44	Jericho	4	MPPNB	Rectilinear	4.00	31.850	35.430	Palestine	Aurenche 1981; Kenyon 1981; Hopf 1983; Hours *et al.* 1994
45	Khirbet Hammam	4	MPPNB	Rectilinear	3.00	31.020	35.650	Jordan	Rollefson 1985; Peterson 2003; Peterson *et al.* 2010
46	Motza V	4	MPPNB	Rectilinear	1.00[b]	31.790	35.170	Israel	Yizhaq *et al.* 2005; Khalaily *et al.* 2007
47	Tell Abu es-Sawwan	4	MPPNB	Rectilinear	3.00	32.219	35.895	Jordan	Al-Nahar 2006; Kroot 2014
48	Tell Aswad II	4	MPPNB	Rectilinear[a]	5.00	33.590	36.380	Syria	Contenson 1979; Stordeur 2003 Chamel 2014
49	Tell Ghoraifé I	4	MPPNB	Rectilinear	3.00	33.830	37.250	Syria	van Zeist and Bakker-Heeres 1982; de Contenson 1995
50	Wadi Shu'eib	4	MPPNB	Rectilinear	3.00	31.920	35.640	Jordan	Simmons 2001; Kroot 2014
51	Yiftah'el IV	4	MPPNB	Rectilinear[a]	1.00	32.720	35.180	Israel	Kislev 1985; Garfinkel *et al.* 1988; Braun 1994; Wright 1992
52	Mishmar Ha’emeq	-	MPPNB	Unknown	0.50	32.609	35.142	Israel	Barzilai and Getzov 2008
53	Munhata IV-VI	-	MPPNB	Unknown[a]	0.20	32.620	35.550	Israel	Cauvin 1978; Kuijt and Bar-Yosef 1994
54	Nahal Betzet I	-	MPPNB	Unknown	0.50	33.070	35.200	Israel	Gopher 1989; Wright 1992
55	Tel Roim West V	-	MPPNB	Unknown	0.50[b]	33.233	35.571	Israel	Nadel and Nadler-Uziel 2011; Rosenberg and Nadel 2014
56	Beidha	3	LPPNB	Rectilinear	0.30	30.370	35.450	Jordan	Helbaek 1966; Aurenche 1981; Byrd 1989; 1994; Colledge 2001
57	‘Ail IV	4	LPPNB	Rectilinear	2.00[b]	29.967	35.367	Jordan	Gebel 2004b; 2008; Asouti 2006; Purschwitz 2013
58	Ba'ja	4	LPPNB	Rectilinear	1.35	30.240	35.270	Jordan	Gebel and Hermansen 2001; 2004; Kinzel 2004; Gebel *et al.* 2006
59	El Hemmeh	4	LPPNB	Rectilinear	1.00	30.970	35.730	Jordan	Makarewicz and Austin 2006; White and Makarewicz 2012
60	Er-Rahib	4	LPPNB	Rectilinear	3.00	32.390	35.730	Jordan	Palumbro and Mabry 1990; Vries and Bikai 1993; Peterman 1994
61	Jericho	4	LPPNB	Rectilinear	4.00	31.850	35.430	Palestine	Aurenche 1981; Kenyon 1981; Hopf 1983; Hours *et al.* 1994
62	Motza Tahtit	4	LPPNB	Rectilinear	2.00[b]	31.791	35.164	Israel	Mizrahi 2015
63	Qminas	4	LPPNB	Rectilinear	1.50	35.894	36.674	Syria	Masuda and Sha'ath 1983; Hours *et al.* 1994; Akkermans 2003
64	Tell Aray	4	LPPNB	Rectilinear	5.00	35.949	36.535	Syria	Tsuneki 2012
65	Tell el-Ghafar I	4	LPPNB	Rectilinear	1.50	35.971	36.468	Syria	Tsuneki 2012
66	Tell Eli III	4	LPPNB	Rectilinear	5.00[b]	32.680	35.550	Israel	Garfinkel 1993; Kroot 2014
67	Tell Ghoraifé II	4	LPPNB	Rectilinear	5.00	33.830	37.250	Syria	van Zeist and Bakker-Heeres 1982; de Contenson 1995
68	Tell Labwé	4	LPPNB	Rectilinear	5.00[b]	34.150	36.350	Lebanon	Ibanez *et al.* 2012; Haidar-Boustani *et al.* 2007
69	Tell Rakan I	4	LPPNB	Rectilinear	1.00	30.802	35.650	Jordan	Banning and Najjar 1999; Banning 2001
70	Tell Ramad I	4	LPPNB	Rectilinear[a]	1.50	33.420	36.100	Syria	Bar-Yosef 1995; Goring-Morris 2000; de Contenson 2000
71	Tell Ras Shamra V C	4	LPPNB	Rectilinear	5.00	35.620	35.780	Syria	van Zeist and Bakker-Heeres 1984

ID	Site name	Site type	Period	Predominant architectural form	Site extent (ha)	Latitude	Longitude	Country	References
72	Tel Tif'dan	4	LPPNB	Rectilinear	3.00	30.670	35.370	Jordan	Adams 1991; Colledge 2001; Twiss 2007; Moreno 2009; Kroot 2014
73	Wadi Badda	4	LPPNB	Rectilinear	1.00	30.600	35.620	Jordan	Fujii 2007
74	Yiftah'el III	4	LPPNB	Rectilinear	1.50	32.720	35.180	Israel	Kislev 1985; Garfinkel *et al.* 1988; Braun 1994; Wright 1992
75	'Ain Ghazal	5	LPPNB	Rectilinear	10.00	31.988	35.976	Jordan	Banning 1984; Rollefson 1986; 1992; 2000; Campbell 2009
76	'Ain Jamam	5	LPPNB	Rectilinear	7.00	30.017	35.517	Jordan	Waheeb and Fino 1997; Henry 2003; Rollefson 2005
77	Al-Baseet	5	LPPNB	Rectilinear	7.50	30.350	35.467	Jordan	Rollefson 2002; Gebel 2004b; Kinzel 2004
78	Basta	5	LPPNB	Rectilinear	13.00	30.230	35.530	Jordan	Nissen 1987; Gebel 1988; Vries 1992
79	Beisamoun	5	LPPNB	Rectilinear	13.50	33.120	35.570	Israel	Lechevallier 1978
80	Es-Sifiya	5	LPPNB	Rectilinear	8.00	31.470	35.570	Jordan	Mahasneh 1997; Kuijt and Goring-Morris 2002
81	Kharaysin	5	LPPNB	Rectilinear	10.00[b]	32.210	36.000	Jordan	Edwards and Thorpe 1986; Edwards 2004
82	Khirbet Hammam	5	LPPNB	Rectilinear	7.00	31.020	35.650	Jordan	Rollefson 1985; Peterson 2003; Peterson *et al.* 2010
83	Tell Abu es-Sawwan	5	LPPNB	Rectilinear	10.50	32.219	35.895	Jordan	Al-Nahar 2006; Kroot 2014
84	Tell 'Ain el-Kerkh/II	5	LPPNB	Rectilinear	16.00	35.810	36.460	Syria	Tsuneki *et al.* 2006; Akkermans 2010; Tsuneki 2012
85	Wadi Shu'eib	5	LPPNB	Rectilinear	8.00[b]	31.920	35.640	Jordan	Simmons 2001; Kroot 2014
86	Aviel	-	LPPNB	Unknown	3.00[b]	32.580	34.980	Israel	Barkai and Biran 2011; Kroot 2014
87	Es-Sayyeh	-	LPPNB	Unknown	3.50[b]	32.192	35.809	Jordan	Kafafi *et al.* 1999; Kuijt and Goring-Morris 2002
88	Atlit-Yam	4	PPNC	Rectilinear	3.00	32.700	34.940	Israel	Galili 1993
89	El Hemmeh	4	PPNC	Rectilinear	1.00	30.970	35.730	Jordan	Makarewicz and Austin 2006; White and Makarewicz 2012
90	Es-Sifiya	4	PPNC	Rectilinear	5.00	31.470	35.570	Jordan	Mahasneh 1997; Kuijt and Goring-Morris 2002
91	Hagoshrim VI	4	PPNC	Rectilinear	3.50[b]	33.183	35.633	Israel	Haber and Dayan 2004; Rosenberg and Getzov 2006
92	Tell Abu es-Sawwan	4	PPNC	Rectilinear	5.00	32.219	35.895	Jordan	Al-Nahar 2006
93	Tell 'Ain el-Kerkh/II	4	PPNC	Rectilinear	6.00	35.810	36.460	Syria	Tsuneki *et al.* 2006; Akkermans 2010; Tsuneki 2012
94	Tell Eli III	4	PPNC	Rectilinear	3.50[b]	32.680	35.550	Israel	Garfinkel 1993; Kroot 2014
95	Tell Labwé	4	PPNC	Rectilinear	3.50[b]	34.150	36.350	Lebanon	Ibanez *et al.* 2012
96	Tell Ramad II	4	PPNC	Rectilinear[a]	2.60	33.420	36.100	Syria	Bar-Yosef 1995; Goring-Morris 2000; de Contenson 2000
97	Tell Ras Shamra V B	4	PPNC	Rectilinear	3.00	35.620	35.780	Syria	van Zeist and Bakker-Heeres 1984
98	Tell Teov	4	PPNC	Rectilinear	3.50[b]	33.067	35.517	Israel	Eisenberg *et al.* 2001; Horwitz 2001; Horwitz and Ducos 2005
99	Tel Roim West IV	4	PPNC	Rectilinear	1.00	33.233	35.571	Israel	Nadel and Nadler-Uziel 2011; Rosenberg and Nadel 2014
100	Wadi Shu'eib	4	PPNC	Rectilinear	6.00[b]	31.920	35.640	Jordan	Simmons 2001; Kroot 2014
101	Yiftah'el III (?)	4	PPNC	Rectilinear	1.50	32.720	35.180	Israel	Kislev 1985; Garfinkel *et al.* 1988; Braun 1994; Wright 1992
102	'Ain Ghazal	5	PPNC	Rectilinear	8.00	31.988	35.976	Jordan	Banning 1984; Rollefson 1986; 1992; 2000; Campbell 2009
103	Basta (?)	5	PPNC	Rectilinear	7.00	30.230	35.530	Jordan	Nissen 1987; Gebel 1988; Vries 1992
104	Beisamoun	5	PPNC	Rectilinear	7.00	33.120	35.570	Israel	Lechevallier 1978
105	Es-Sayyeh	-	PPNC	Unknown[a]	2.00[b]	32.192	35.809	Jordan	Kafafi *et al.* 1999; Kuijt and Goring-Morris 2002
106	Wadi Fidan C	-	PPNC	Unknown	1.50[b]	30.620	35.500	Jordan	Colledge 2001

[a] Transitional.
[b] Site size suggested based on site size analysis.

Appendix E.2: Data produced from systematic methodologies

Regional population density coefficient method (RPDC)

Period	ID	Site name	Site type	Site extent (ha)	Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNA	1	Ain Darat	1	0.08	6	35	**18**	14	7	126	**45**	47
	2	Bir el-Maksur	1	0.20	15	86	**46**	35	18	316	**112**	118
	3	Borj Barajne	1	0.20	15	86	**46**	35	18	316	**112**	118
	4	Ein Suhun	1	0.30	22	130	**69**	52	27	474	**168**	177
	5	El Aoui Safa	1	0.20	15	86	**46**	35	18	316	**112**	118
	6	El Hemmeh	1	0.10	7	43	**23**	17	9	158	**56**	59
	7	Gesher	1	0.15	11	65	**34**	26	13	237	**84**	89
	8	Gilgal III	1	0.10	7	43	**23**	17	9	158	**56**	59
	9	Gilgal IV	1	0.10	7	43	**23**	17	9	158	**56**	59
	10	Hatoula	1	0.20	15	86	**46**	35	18	316	**112**	118
	11	Nahal Oren	1	0.05	4	22	**11**	9	4	79	**28**	30
	12	Zahrat Adh-Dhra' 2	1	0.20	15	86	**46**	35	18	316	**112**	118
	13	Dhra'	2	0.45	30	75	**53**	78	102	364	**216**	266
	14	Gilgal I	2	0.40	27	67	**47**	69	90	323	**192**	236
	15	Huzuq Musa	2	1.00	67	168	**118**	174	226	808	**480**	590
	16	Jericho	2	2.50	169	419	**294**	434	565	2021	**1201**	1475
	17	Netiv Hagdud	2	0.75	51	126	**88**	130	169	606	**360**	443
	18	Tell Aswad IA	2	1.00	67	168	**118**	174	226	808	**480**	590
EPPNB	19	Ain Abu Hudhud	1	0.20	15	86	**46**	35	18	316	**112**	118
	20	Ein Suhun	1	0.30	22	130	**69**	52	27	474	**168**	177
	21	El Hemmeh	1	0.10	7	43	**23**	17	9	158	**56**	59
	22	Motza VI	2	0.50	34	84	**59**	87	113	404	**240**	295
	23	Mujahiya	2	0.50	34	84	**59**	87	113	404	**240**	295
	24	Tell Aswad IB	2	1.00	67	168	**118**	174	226	808	**480**	590
	25	Horvat Galil	4	1.00	80	246	**151**	174	212	1165	**546**	590
	26	Tell Qarassa	4	1.00	80	246	**151**	174	212	1165	**546**	590
	27	Mishmar Ha'emeq	-	1.00	67	432	**174**	174	81	2853	**590**	590

Period	ID	Site name	Site type	Site extent (ha)	Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
MPPNB	28	Adh-Dhaman I	1	0.20	15	86	**46**	35	18	316	**112**	118
	29	Ain Abu Nekheileh	1	0.12	9	52	**27**	21	11	190	**67**	71
	30	Beidha	1	0.20	15	86	**46**	35	18	316	**112**	118
	31	Jebel Arqa	1	0.20	15	86	**46**	35	18	316	**112**	118
	32	Jebel Rabigh	1	0.06	4	26	**14**	10	5	95	**34**	35
	33	Jebel Ragref	1	0.15	11	65	**34**	26	13	237	**84**	89
	34	Jebel Salaqa	1	0.10	7	43	**23**	17	9	158	**56**	59
	35	Shkārat Msaied	1	0.20	15	86	**46**	35	18	316	**112**	118
	36	Tell Eli IV	2	2.00	135	335	**235**	347	452	1617	**960**	1180
	37	Abu Gosh	3	0.25	25	30	**28**	43	93	155	**122**	148
	38	Wadi Hamarash I	3	0.50	50	61	**55**	87	186	311	**245**	295
	39	Ail IV	4	1.00	80	246	**151**	174	212	1165	**546**	590
	40	'Ain Ghazal	4	4.00	320	985	**606**	694	848	4661	**2186**	2360
	41	Beisamoun	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	42	Ghwair I	4	1.325	106	326	**201**	230	281	1544	**724**	782
	43	Horvat Galil	4	2.50	200	616	**379**	434	530	2913	**1366**	1475
	44	Jericho	4	4.00	320	985	**606**	694	848	4661	**2186**	2360
	45	Khirbet Hammam	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	46	Motza V	4	1.00	80	246	**151**	174	212	1165	**546**	590
	47	Tell Abu es-Sawwan	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	48	Tell Aswad II	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	49	Tell Ghoraifé I	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	50	Wadi Shu'eib	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	51	Yiftah'el IV	4	1.00	80	246	**151**	174	212	1165	**546**	590
	52	Mishmar Ha'emeq	-	0.50	34	216	**87**	87	40	1427	**295**	295
	53	Munhata IV-VI	-	0.20	13	86	**35**	35	16	571	**118**	118
	54	Nahal Betzet I	-	0.50	34	216	**87**	87	40	1427	**295**	295
	55	Tel Roim West V	-	0.50	34	216	**87**	87	40	1427	**295**	295

Period	ID	Site name	Site type	Site extent (ha)	Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
LPPNB	56	Beidha	3	0.30	30	37	**33**	52	112	187	**147**	177
	57	Ail IV	4	2.00	160	492	**303**	347	424	2330	**1093**	1180
	58	Ba'ja	4	1.35	108	332	**204**	234	286	1573	**738**	797
	59	El Hemmeh	4	1.00	80	246	**151**	174	212	1165	**546**	590
	60	Er-Rahib	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	61	Jericho	4	4.00	320	985	**606**	694	848	4661	**2186**	2360
	62	Moẕa Tahtit	4	2.00	160	492	**303**	347	424	2330	**1093**	1180
	63	Qminas	4	1.50	120	369	**227**	260	318	1748	**820**	885
	64	Tell Aray	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	65	Tell el-Ghafar I	4	1.50	120	369	**227**	260	318	1748	**820**	885
	66	Tell Eli III	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	67	Tell Ghoraifé II	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	68	Tell Labwé	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	69	Tell Rakan I	4	1.00	80	246	**151**	174	212	1165	**546**	590
	70	Tell Ramad I	4	1.50	120	369	**227**	260	318	1748	**820**	885
	71	Tell Ras Shamra V C	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	72	Tel Tif'dan	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	73	Wadi Badda	4	1.00	80	246	**151**	174	212	1165	**546**	590
	74	Yiftah'el III	4	1.50	120	369	**227**	260	318	1748	**820**	885
	75	'Ain Ghazal	5	10.00	-	-	**923**	1736	4428	6089	**5259**	5901
	76	Ain Jamam	5	7.00	-	-	**646**	1215	3100	4262	**3681**	4131
	77	Al-Baseet	5	7.50	-	-	**692**	1302	3321	4567	**3944**	4426
	78	Basta	5	13.00	-	-	**1199**	2256	5757	7916	**6836**	7671
	79	Beisamoun	5	13.50	-	-	**1245**	2343	5978	8220	**7099**	7966
	80	Es-Sifiya	5	8.00	-	-	**738**	1388	3543	4871	**4207**	4721
	81	Kharaysin	5	10.00	-	-	**923**	1736	4428	6089	**5259**	5901
	82	Khirbet Hammam	5	7.00	-	-	**646**	1215	3100	4262	**3681**	4131
	83	Tell Abu es-Sawwan	5	10.50	-	-	**969**	1822	4650	6394	**5522**	6196
	84	Tell 'Ain el-Kerkh/II	5	16.00	-	-	**1476**	2777	7086	9743	**8414**	9442
	85	Wadi Shu'eib	5	8.00	-	-	**738**	1388	3543	4871	**4207**	4721
	86	Aviel	-	3.00	202	1297	**521**	521	243	8560	**1770**	1770
	87	Es-Sayyeh	-	3.50	236	1513	**607**	607	283	9987	**2065**	2065

Period	ID	Site name	Site type	Site extent (ha)	Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNC	88	Atlit-Yam	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	89	El Hemmeh	4	1.00	80	246	**151**	174	212	1165	**546**	590
	90	Es-Sifiya	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	91	Hagoshrim VI	4	3.50	280	862	**530**	607	742	4078	**1913**	2065
	92	Tell Abu es-Sawwan	4	5.00	400	1231	**757**	868	1060	5826	**2732**	2951
	93	Tell 'Ain el-Kerkh/II	4	6.00	479	1477	**909**	1041	1272	6991	**3279**	3541
	94	Tell Eli III	4	3.50	280	862	**530**	607	742	4078	**1913**	2065
	95	Tell Labwé	4	3.50	280	862	**530**	607	742	4078	**1913**	2065
	96	Tell Ramad II	4	2.60	208	640	**394**	451	551	3029	**1421**	1534
	97	Tell Ras Shamra V B	4	3.00	240	739	**454**	521	636	3495	**1639**	1770
	98	Tell Teo	4	3.50	280	862	**530**	607	742	4078	**1913**	2065
	99	Tel Roim West IV	4	1.00	80	246	**151**	174	212	1165	**546**	590
	100	Wadi Shu'eib	4	6.00	479	1477	**909**	1041	1272	6991	**3279**	3541
	101	Yiftah'el III (?)	4	1.50	120	369	**227**	260	318	1748	**820**	885
	102	'Ain Ghazal	5	8.00	-	-	**738**	1388	3543	4871	**4207**	4721
	103	Basta (?)	5	7.00	-	-	**646**	1215	3100	4262	**3681**	4131
	104	Beisamoun	5	7.00	-	-	**646**	1215	3100	4262	**3681**	4131
	105	Es-Sayyeh	-	2.00	135	865	**347**	347	162	5707	**1180**	1180
	106	Wadi Fidan C	-	1.50	101	649	**260**	260	121	4280	**885**	885

Residential built area proportions method (RBAP)

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential built area (m^2)				Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNA	1	Ain Darat	1	0.08	239	437	**313**	250	17	32	**19**	12	20	115	**48**	42
	2	Bir el-Maksur	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	3	Borj Barajne	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	4	Ein Suhun	1	0.30	895	1637	**1172**	938	62	118	**73**	46	76	433	**179**	156
	5	El Aoui Safa	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	6	El Hemmeh	1	0.10	298	546	**391**	313	21	39	**24**	15	25	144	**60**	52
	7	Gesher	1	0.15	448	819	**586**	469	31	59	**36**	23	38	216	**89**	78
	8	Gilgal III	1	0.10	298	546	**391**	313	21	39	**24**	15	25	144	**60**	52
	9	Gilgal IV	1	0.10	298	546	**391**	313	21	39	**24**	15	25	144	**60**	52
	10	Hatoula	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	11	Nahal Oren	1	0.05	149	273	**195**	156	10	20	**12**	8	13	72	**30**	26
	12	Zahrat Adh-Dhra' 2	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	13	Dhra'	2	0.45	856	944	**900**	1408	33	54	**41**	69	112	259	**166**	233
	14	Gilgal I	2	0.40	761	839	**800**	1251	30	48	**36**	61	100	230	**148**	208
	15	Huzuq Musa	2	1.00	1902	2097	**2000**	3128	74	119	**91**	153	249	575	**370**	519
	16	Jericho	2	2.50	4755	5243	**4999**	7820	186	298	**226**	381	622	1437	**925**	1297
	17	Netiv Hagdud	2	0.75	1427	1573	**1500**	2346	56	89	**68**	114	187	431	**277**	389
	18	Tell Aswad IA	2	1.00	1902	2097	**2000**	3128	74	119	**91**	153	249	575	**370**	519
EPPNB	19	Ain Abu Hudhud	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	20	Ein Suhun	1	0.30	895	1637	**1172**	938	62	118	**73**	46	76	433	**179**	156
	21	El Hemmeh	1	0.10	298	546	**391**	313	21	39	**24**	15	25	144	**60**	52
	22	Motza VI	2	0.50	951	1049	**1000**	1564	37	60	**45**	76	124	287	**185**	259
	23	Mujahiya	2	0.50	951	1049	**1000**	1564	37	60	**45**	76	124	287	**185**	259
	24	Tell Aswad IB	2	1.00	1902	2097	**2000**	3128	74	119	**91**	153	249	575	**370**	519
	25	Horvat Galil	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	26	Tell Qarassa	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	27	Mishmar Ha'emeq	-	1.00	1715	5457	**3128**	3128	185	226	**153**	153	222	1489	**519**	519

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential built area (m^2)				Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**		*Min*	*Max*	**Mean**	
MPPNB	28	Adh-Dhaman I	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	29	Ain Abu Nekheileh	1	0.12	358	655	**469**	375	25	47	**29**	18	30	173	**71**	62
	30	Beidha	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	31	Jebel Arqa	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	32	Jebel Rabigh	1	0.06	179	327	**234**	188	12	24	**15**	9	15	87	**36**	31
	33	Jebel Ragref	1	0.15	448	819	**586**	469	31	59	**36**	23	38	216	**89**	78
	34	Jebel Salaqa	1	0.10	298	546	**391**	313	21	39	**24**	15	25	144	**60**	52
	35	Shkārat Msaied	1	0.20	597	1091	**781**	626	41	79	**49**	31	51	288	**119**	104
	36	Tell Eli IV	2	2.00	3804	4194	**3999**	6256	149	238	**181**	305	498	1150	**740**	1038
	37	Abu Gosh	3	0.25	429	696	**562**	782	24	20	**22**	38	88	104	**98**	130
	38	Wadi Hamarash I	3	0.50	858	1392	**1125**	1564	47	41	**44**	76	175	208	**196**	259
	39	Ail IV	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	40	'Ain Ghazal	4	4.00	7684	13028	**10879**	12512	542	502	**522**	610	1438	2374	**1883**	2075
	41	Beisamoun	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	42	Ghwair I	4	1.325	2545	4316	**3604**	4145	180	166	**173**	202	476	786	**624**	687
	43	Horvat Galil	4	2.50	4803	8143	**6799**	7820	339	313	**326**	381	898	1484	**1177**	1297
	44	Jericho	4	4.00	7684	13028	**10879**	12512	542	502	**522**	610	1438	2374	**1883**	2075
	45	Khirbet Hammam	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	46	Motza V	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	47	Tell Abu es-Sawwan	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	48	Tell Aswad II	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	49	Tell Ghoraifé I	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	50	Wadi Shu'eib	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	51	Yiftah'el IV	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	52	Mishmar Ha'emeq	-	0.50	858	2729	**1564**	1564	92	113	**76**	76	111	745	**259**	259
	53	Munhata IV-VI	-	0.20	343	1091	**626**	626	37	45	**31**	31	44	298	**104**	104
	54	Nahal Betzet I	-	0.50	858	2729	**1564**	1564	92	113	**76**	76	111	745	**259**	259
	55	Tel Roim West V	-	0.50	858	2729	**1564**	1564	92	113	**76**	76	111	745	**259**	259

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential built area (m^2)				Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**		*Min*	*Max*	**Mean**	
LPPNB	56	Beidha	3	0.30	515	835	**675**	938	28	24	**27**	46	105	125	**118**	156
	57	Ail IV	4	2.00	3842	6514	**5439**	6256	271	251	**261**	305	719	1187	**941**	1038
	58	Ba'ja	4	1.35	2593	4397	**3672**	4223	183	169	**176**	206	485	801	**635**	700
	59	El Hemmeh	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	60	Er-Rahib	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	61	Jericho	4	4.00	7684	13028	**10879**	12512	542	502	**522**	610	1438	2374	**1883**	2075
	62	Moẕa Tahtit	4	2.00	3842	6514	**5439**	6256	271	251	**261**	305	719	1187	**941**	1038
	63	Qminas	4	1.50	2882	4886	**4080**	4692	203	188	**196**	229	539	890	**706**	778
	64	Tell Aray	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	65	Tell el-Ghafar I	4	1.50	2882	4886	**4080**	4692	203	188	**196**	229	539	890	**706**	778
	66	Tell Eli III	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	67	Tell Ghoraifé II	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	68	Tell Labwé	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	69	Tell Rakan I	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	70	Tell Ramad I	4	1.50	2882	4886	**4080**	4692	203	188	**196**	229	539	890	**706**	778
	71	Tell Ras Shamra V C	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	72	Tel Tif'dan	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	73	Wadi Badda	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	74	Yiftah'el III	4	1.50	2882	4886	**4080**	4692	203	188	**196**	229	539	890	**706**	778
	75	'Ain Ghazal	5	10.00	-	-	**36950**	31280	783	1369	**996**	1526	3758	9032	**5677**	5188
	76	Ain Jamam	5	7.00	-	-	**25865**	21896	548	958	**697**	1068	2630	6323	**3974**	3632
	77	Al-Baseet	5	7.50	-	-	**27713**	23460	587	1026	**747**	1144	2818	6774	**4258**	3891
	78	Basta	5	13.00	-	-	**48035**	40664	1018	1779	**1295**	1984	4885	11742	**7380**	6744
	79	Beisamoun	5	13.50	-	-	**49883**	42228	1057	1848	**1345**	2060	5073	12194	**7664**	7004
	80	Es-Sifiya	5	8.00	-	-	**29560**	25024	626	1095	**797**	1221	3006	7226	**4542**	4150
	81	Kharaysin	5	10.00	-	-	**36950**	31280	783	1369	**996**	1526	3758	9032	**5677**	5188
	82	Khirbet Hammam	5	7.00	-	-	**25865**	21896	548	958	**697**	1068	2630	6323	**3974**	3632
	83	Tell Abu es-Sawwan	5	10.50	-	-	**38798**	32844	822	1437	**1046**	1602	3946	9484	**5961**	5447
	84	Tell 'Ain el-Kerkh/II	5	16.00	-	-	**59120**	50048	1253	2190	**1594**	2441	6012	14452	**9083**	8301
	85	Wadi Shu'eib	5	8.00	-	-	**29560**	25024	626	1095	**797**	1221	3006	7226	**4542**	4150
	86	Aviel	-	3.00	5145	16371	**9384**	9384	555	677	**458**	458	666	4468	**1556**	1556
	87	Es-Sayyeh	-	3.50	6003	19100	**10948**	10948	647	790	**534**	534	777	5213	**1816**	1816

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential built area (m²)				Total number of contemporaneous dwellings				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNC	88	Atlit-Yam	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	89	El Hemmeh	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	90	Es-Sifiya	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	91	Hagoshrim VI	4	3.50	6724	11400	**9519**	10948	474	439	**457**	534	1258	2077	**1647**	1816
	92	Tell Abu es-Sawwan	4	5.00	9605	16285	**13598**	15640	677	627	**652**	763	1797	2967	**2353**	2594
	93	Tell 'Ain el-Kerkh/II	4	6.00	11526	19542	**16318**	18768	813	752	**783**	916	2156	3561	**2824**	3113
	94	Tell Eli III	4	3.50	6724	11400	**9519**	10948	474	439	**457**	534	1258	2077	**1647**	1816
	95	Tell Labwé	4	3.50	6724	11400	**9519**	10948	474	439	**457**	534	1258	2077	**1647**	1816
	96	Tell Ramad II	4	2.60	4995	8468	**7071**	8133	352	326	**339**	397	934	1543	**1224**	1349
	97	Tell Ras Shamra V B	4	3.00	5763	9771	**8159**	9384	406	376	**391**	458	1078	1780	**1412**	1556
	98	Tell Teo	4	3.50	6724	11400	**9519**	10948	474	439	**457**	534	1258	2077	**1647**	1816
	99	Tel Roim West IV	4	1.00	1921	3257	**2720**	3128	135	125	**130**	153	359	593	**471**	519
	100	Wadi Shu'eib	4	6.00	11526	19542	**16318**	18768	813	752	**783**	916	2156	3561	**2824**	3113
	101	Yiftah'el III (?)	4	1.50	2882	4886	**4080**	4692	203	188	**196**	229	539	890	**706**	778
	102	'Ain Ghazal	5	8.00	-	-	**29560**	25024	626	1095	**797**	1221	3006	7226	**4542**	4150
	103	Basta (?)	5	7.00	-	-	**25865**	21896	548	958	**697**	1068	2630	6323	**3974**	3632
	104	Beisamoun	5	7.00	-	-	**25865**	21896	548	958	**697**	1068	2630	6323	**3974**	3632
	105	Es-Sayyeh	-	2.00	3430	10914	**6256**	6256	370	451	**305**	305	444	2979	**1038**	1038
	106	Wadi Fidan C	-	1.50	2573	8186	**4692**	4692	277	338	**229**	229	333	2234	**778**	778

Residential floor area proportions method (RFAP)

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2)				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNA	1	Ain Darat	1	0.08	119	257	**176**	149	32	89	**53**	43
	2	Bir el-Maksur	1	0.20	297	643	**440**	372	79	222	**132**	108
	3	Borj Barajne	1	0.20	297	643	**440**	372	79	222	**132**	108
	4	Ein Suhun	1	0.30	446	964	**660**	558	119	333	**198**	162
	5	El Aoui Safa	1	0.20	297	643	**440**	372	79	222	**132**	108
	6	El Hemmeh	1	0.10	149	321	**220**	186	40	111	**66**	54
	7	Gesher	1	0.15	223	482	**330**	279	60	167	**99**	81
	8	Gilgal III	1	0.10	149	321	**220**	186	40	111	**66**	54
	9	Gilgal IV	1	0.10	149	321	**220**	186	40	111	**66**	54
	10	Hatoula	1	0.20	297	643	**440**	372	79	222	**132**	108
	11	Nahal Oren	1	0.05	74	161	**110**	93	20	56	**33**	27
	12	Zahrat Adh-Dhra' 2	1	0.20	297	643	**440**	372	79	222	**132**	108
	13	Dhra'	2	0.45	648	746	**697**	837	143	223	**177**	243
	14	Gilgal I	2	0.40	576	663	**619**	744	127	198	**157**	216
	15	Huzuq Musa	2	1.00	1439	1658	**1549**	1861	318	495	**393**	541
	16	Jericho	2	2.50	3598	4145	**3871**	4653	795	1238	**983**	1352
	17	Netiv Hagdud	2	0.75	1079	1244	**1161**	1396	238	372	**295**	406
	18	Tell Aswad IA	2	1.00	1439	1658	**1549**	1861	318	495	**393**	541
EPPNB	19	Ain Abu Hudhud	1	0.20	297	643	**440**	372	79	222	**132**	108
	20	Ein Suhun	1	0.30	446	964	**660**	558	119	333	**198**	162
	21	El Hemmeh	1	0.10	149	321	**220**	186	40	111	**66**	54
	22	Motza VI	2	0.50	720	829	**774**	931	159	248	**197**	270
	23	Mujahiya	2	0.50	720	829	**774**	931	159	248	**197**	270
	24	Tell Aswad IB	2	1.00	1439	1658	**1549**	1861	318	495	**393**	541
	25	Horvat Galil	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	26	Tell Qarassa	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	27	Mishmar Ha'emeq	-	1.00	1133	3213	**1861**	1861	250	1112	**541**	541

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2)				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
MPPNB	28	Adh-Dhaman I	1	0.20	297	643	**440**	372	79	222	**132**	108
	29	Ain Abu Nekheileh	1	0.12	178	386	**264**	223	48	133	**79**	65
	30	Beidha	1	0.20	297	643	**440**	372	79	222	**132**	108
	31	Jebel Arqa	1	0.20	297	643	**440**	372	79	222	**132**	108
	32	Jebel Rabigh	1	0.06	89	193	**132**	112	24	67	**40**	32
	33	Jebel Ragref	1	0.15	223	482	**330**	279	60	167	**99**	81
	34	Jebel Salaqa	1	0.10	149	321	**220**	186	40	111	**66**	54
	35	Shkārat Msaied	1	0.20	297	643	**440**	372	79	222	**132**	108
	36	Tell Eli IV	2	2.00	2878	3316	**3097**	3722	636	991	**787**	1082
	37	Abu Gosh	3	0.25	283	419	**351**	465	88	142	**114**	135
	38	Wadi Hamarash I	3	0.50	567	839	**703**	931	177	284	**228**	270
	39	Ail IV	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	40	'Ain Ghazal	4	4.00	4840	8532	**6889**	7444	1172	2571	**1915**	2164
	41	Beisamoun	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	42	Ghwair I	4	1.325	1603	2826	**2282**	2466	388	852	**634**	717
	43	Horvat Galil	4	2.50	3025	5333	**4306**	4653	732	1607	**1197**	1352
	44	Jericho	4	4.00	4840	8532	**6889**	7444	1172	2571	**1915**	2164
	45	Khirbet Hammam	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	46	Motza V	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	47	Tell Abu es-Sawwan	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	48	Tell Aswad II	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	49	Tell Ghoraifé I	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	50	Wadi Shu'eib	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	51	Yiftah'el IV	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	52	Mishmar Ha'emeq	-	0.50	567	1607	**931**	931	125	556	**270**	270
	53	Munhata IV-VI	-	0.20	227	643	**372**	372	50	222	**108**	108
	54	Nahal Betzet I	-	0.50	567	1607	**931**	931	125	556	**270**	270
	55	Tel Roim West V	-	0.50	567	1607	**931**	931	125	556	**270**	270

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2)				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
LPPNB	56	Beidha	3	0.30	340	503	**422**	558	106	170	**137**	162
	57	Ail IV	4	2.00	2420	4266	**3445**	3722	586	1285	**957**	1082
	58	Ba'ja	4	1.35	1634	2880	**2325**	2512	396	868	**646**	730
	59	El Hemmeh	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	60	Er-Rahib	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	61	Jericho	4	4.00	4840	8532	**6889**	7444	1172	2571	**1915**	2164
	62	Moẕa Tahtit	4	2.00	2420	4266	**3445**	3722	586	1285	**957**	1082
	63	Qminas	4	1.50	1815	3200	**2584**	2792	439	964	**718**	811
	64	Tell Aray	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	65	Tell el-Ghafar I	4	1.50	1815	3200	**2584**	2792	439	964	**718**	811
	66	Tell Eli III	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	67	Tell Ghoraifé II	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	68	Tell Labwé	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	69	Tell Rakan I	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	70	Tell Ramad I	4	1.50	1815	3200	**2584**	2792	439	964	**718**	811
	71	Tell Ras Shamra V C	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	72	Tel Tif'dan	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	73	Wadi Badda	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	74	Yiftah'el III	4	1.50	1815	3200	**2584**	2792	439	964	**718**	811
	75	'Ain Ghazal	5	10.00	-	-	**17680**	18610	4420	6097	**5051**	5410
	76	Ain Jamam	5	7.00	-	-	**12376**	13027	3094	4268	**3536**	3787
	77	Al-Baseet	5	7.50	-	-	**13260**	13958	3315	4572	**3789**	4057
	78	Basta	5	13.00	-	-	**22984**	24193	5746	7926	**6567**	7033
	79	Beisamoun	5	13.50	-	-	**23868**	25124	5967	8230	**6819**	7303
	80	Es-Sifiya	5	8.00	-	-	**14144**	14888	3536	4877	**4041**	4328
	81	Kharaysin	5	10.00	-	-	**17680**	18610	4420	6097	**5051**	5410
	82	Khirbet Hammam	5	7.00	-	-	**12376**	13027	3094	4268	**3536**	3787
	83	Tell Abu es-Sawwan	5	10.50	-	-	**18564**	19541	4641	6401	**5304**	5680
	84	Tell 'Ain el-Kerkh/II	5	16.00	-	-	**28288**	29776	7072	9754	**8082**	8656
	85	Wadi Shu'eib	5	8.00	-	-	**14144**	14888	3536	4877	**4041**	4328
	86	Aviel	-	3.00	3399	9639	**5583**	5583	750	3335	**1623**	1623
	87	Es-Sayyeh	-	3.50	3966	11246	**6514**	6514	875	3891	**1893**	1893

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2)				Population estimates			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNC	88	Atlit-Yam	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	89	El Hemmeh	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	90	Es-Sifiya	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	91	Hagoshrim VI	4	3.50	4235	7466	**6028**	6514	1025	2249	**1675**	1893
	92	Tell Abu es-Sawwan	4	5.00	6050	10665	**8612**	9305	1465	3213	**2393**	2705
	93	Tell 'Ain el-Kerkh/II	4	6.00	7260	12798	**10334**	11166	1758	3856	**2872**	3246
	94	Tell Eli III	4	3.50	4235	7466	**6028**	6514	1025	2249	**1675**	1893
	95	Tell Labwé	4	3.50	4235	7466	**6028**	6514	1025	2249	**1675**	1893
	96	Tell Ramad II	4	2.60	3146	5546	**4478**	4839	762	1671	**1245**	1407
	97	Tell Ras Shamra V B	4	3.00	3630	6399	**5167**	5583	879	1928	**1436**	1623
	98	Tell Teo	4	3.50	4235	7466	**6028**	6514	1025	2249	**1675**	1893
	99	Tel Roim West IV	4	1.00	1210	2133	**1722**	1861	293	643	**479**	541
	100	Wadi Shu'eib	4	6.00	7260	12798	**10334**	11166	1758	3856	**2872**	3246
	101	Yiftah'el III (?)	4	1.50	1815	3200	**2584**	2792	439	964	**718**	811
	102	'Ain Ghazal	5	8.00	-	-	**14144**	14888	3536	4877	**4041**	4328
	103	Basta (?)	5	7.00	-	-	**12376**	13027	3094	4268	**3536**	3787
	104	Beisamoun	5	7.00	-	-	**12376**	13027	3094	4268	**3536**	3787
	105	Es-Sayyeh	-	2.00	2266	6426	**3722**	3722	500	2224	**1082**	1082
	106	Wadi Fidan C	-	1.50	1700	4820	**2792**	2792	375	1668	**811**	811

Storage provisions formulae (SPF)

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2) (A variable)				Population estimates *(mean of Methods 1 and 2)*			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNA	1	Ain Darat	1	0.08	119	257	**176**	149	34	69	**47**	45
	2	Bir el-Maksur	1	0.20	297	643	**440**	372	84	173	**119**	112
	3	Borj Barajne	1	0.20	297	643	**440**	372	84	173	**119**	112
	4	Ein Suhun	1	0.30	446	964	**660**	558	126	260	**178**	168
	5	El Aoui Safa	1	0.20	297	643	**440**	372	84	173	**119**	112
	6	El Hemmeh	1	0.10	149	321	**220**	186	42	86	**59**	55
	7	Gesher	1	0.15	223	482	**330**	279	63	130	**89**	84
	8	Gilgal III	1	0.10	149	321	**220**	186	42	86	**59**	55
	9	Gilgal IV	1	0.10	149	321	**220**	186	42	86	**59**	55
	10	Hatoula	1	0.20	297	643	**440**	372	84	173	**119**	112
	11	Nahal Oren	1	0.05	74	161	**110**	93	21	43	**29**	29
	12	Zahrat Adh-Dhra' 2	1	0.20	297	643	**440**	372	84	173	**119**	112
	13	Dhra'	2	0.45	648	746	**697**	837	133	298	**208**	240
	14	Gilgal I	2	0.40	576	663	**619**	744	118	264	**184**	212
	15	Huzuq Musa	2	1.00	1439	1658	**1549**	1861	295	664	**463**	533
	16	Jericho	2	2.50	3598	4145	**3871**	4653	737	1651	**1155**	1329
	17	Netiv Hagdud	2	0.75	1079	1244	**1161**	1396	221	495	**346**	398
	18	Tell Aswad IA	2	1.00	1439	1658	**1549**	1861	295	664	**463**	533
EPPNB	19	Ain Abu Hudhud	1	0.20	297	643	**440**	372	84	173	**119**	112
	20	Ein Suhun	1	0.30	446	964	**660**	558	126	260	**178**	168
	21	El Hemmeh	1	0.10	149	321	**220**	186	42	86	**59**	55
	22	Motza VI	2	0.50	720	829	**774**	931	148	330	**231**	266
	23	Mujahiya	2	0.50	720	829	**774**	931	148	330	**231**	266
	24	Tell Aswad IB	2	1.00	1439	1658	**1549**	1861	295	664	**463**	533
	25	Horvat Galil	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	26	Tell Qarassa	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	27	Mishmar Ha'emeq	-	1.00	1133	3213	**1861**	1861	355	751	**546**	546

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2) (A variable)				Population estimates *(mean of Methods 1 and 2)*			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
MPPNB	28	Adh-Dhaman I	1	0.20	297	643	**440**	372	84	173	**119**	112
	29	Ain Abu Nekheileh	1	0.12	178	386	**264**	223	51	104	**71**	67
	30	Beidha	1	0.20	297	643	**440**	372	84	173	**119**	112
	31	Jebel Arqa	1	0.20	297	643	**440**	372	84	173	**119**	112
	32	Jebel Rabigh	1	0.06	89	193	**132**	112	26	52	**36**	33
	33	Jebel Ragref	1	0.15	223	482	**330**	279	63	130	**89**	84
	34	Jebel Salaqa	1	0.10	149	321	**220**	186	42	86	**59**	55
	35	Shkārat Msaied	1	0.20	297	643	**440**	372	84	173	**119**	112
	36	Tell Eli IV	2	2.00	2878	3316	**3097**	3722	590	1321	**924**	1064
	37	Abu Gosh	3	0.25	283	419	**351**	465	87	138	**113**	146
	38	Wadi Hamarash I	3	0.50	567	839	**703**	931	174	277	**225**	293
	39	Ail IV	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	40	'Ain Ghazal	4	4.00	4840	8532	**6889**	7444	1707	2717	**2183**	2424
	41	Beisamoun	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	42	Ghwair I	4	1.325	1603	2826	**2282**	2466	565	900	**723**	803
	43	Horvat Galil	4	2.50	3025	5333	**4306**	4653	1067	1698	**1364**	1515
	44	Jericho	4	4.00	4840	8532	**6889**	7444	1707	2717	**2183**	2424
	45	Khirbet Hammam	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	46	Motza V	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	47	Tell Abu es-Sawwan	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	48	Tell Aswad II	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	49	Tell Ghoraifé I	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	50	Wadi Shu'eib	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	51	Yiftah'el IV	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	52	Mishmar Ha'emeq	-	0.50	567	1607	**931**	931	177	374	**272**	272
	53	Munhata IV-VI	-	0.20	227	643	**372**	372	71	152	**110**	110
	54	Nahal Betzet I	-	0.50	567	1607	**931**	931	177	374	**272**	272
	55	Tel Roim West V	-	0.50	567	1607	**931**	931	177	374	**272**	272

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2) (A variable)				Population estimates *(mean of Methods 1 and 2)*			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
LPPNB	56	Beidha	3	0.30	340	503	**422**	558	104	166	**136**	176
	57	Ail IV	4	2.00	2420	4266	**3445**	3722	853	1358	**1091**	1212
	58	Ba'ja	4	1.35	1634	2880	**2325**	2512	576	917	**736**	818
	59	El Hemmeh	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	60	Er-Rahib	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	61	Jericho	4	4.00	4840	8532	**6889**	7444	1707	2717	**2183**	2424
	62	Moẕa Tahtit	4	2.00	2420	4266	**3445**	3722	853	1358	**1091**	1212
	63	Qminas	4	1.50	1815	3200	**2584**	2792	640	1019	**818**	909
	64	Tell Aray	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	65	Tell el-Ghafar I	4	1.50	1815	3200	**2584**	2792	640	1019	**818**	909
	66	Tell Eli III	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	67	Tell Ghoraifé II	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	68	Tell Labwé	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	69	Tell Rakan I	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	70	Tell Ramad I	4	1.50	1815	3200	**2584**	2792	640	1019	**818**	909
	71	Tell Ras Shamra V C	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	72	Tel Tif'dan	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	73	Wadi Badda	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	74	Yiftah'el III	4	1.50	1815	3200	**2584**	2792	640	1019	**818**	909
	75	'Ain Ghazal	5	10.00	-	-	**17680**	18610	4379	6283	**5331**	4763
	76	Ain Jamam	5	7.00	-	-	**12376**	13027	3066	4397	**3731**	3333
	77	Al-Baseet	5	7.50	-	-	**13260**	13958	3285	4712	**3998**	3572
	78	Basta	5	13.00	-	-	**22984**	24193	5693	8166	**6930**	6191
	79	Beisamoun	5	13.50	-	-	**23868**	25124	5912	8480	**7196**	6429
	80	Es-Sifiya	5	8.00	-	-	**14144**	14888	3504	5026	**4265**	3810
	81	Kharaysin	5	10.00	-	-	**17680**	18610	4379	6283	**5331**	4763
	82	Khirbet Hammam	5	7.00	-	-	**12376**	13027	3066	4397	**3731**	3333
	83	Tell Abu es-Sawwan	5	10.50	-	-	**18564**	19541	4598	6598	**5598**	5000
	84	Tell 'Ain el-Kerkh/II	5	16.00	-	-	**28288**	29776	7007	10052	**8529**	7619
	85	Wadi Shu'eib	5	8.00	-	-	**14144**	14888	3504	5026	**4265**	3810
	86	Aviel	-	3.00	3399	9639	**5583**	5583	1063	2249	**1635**	1635
	87	Es-Sayyeh	-	3.50	3966	11246	**6514**	6514	1240	2621	**1906**	1906

Period	ID	Site name	Site type	Site extent (ha)	Total contemporaneous residential floor area (m^2) (A variable)				Population estimates *(mean of Methods 1 and 2)*			
					Site type			*Universal*	*Site type*			*Universal*
					Min	*Max*	**Mean**		*Min*	*Max*	**Mean**	
PPNC	88	Atlit-Yam	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	89	El Hemmeh	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	90	Es-Sifiya	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	91	Hagoshrim VI	4	3.50	4235	7466	**6028**	6514	1493	2377	**1910**	2121
	92	Tell Abu es-Sawwan	4	5.00	6050	10665	**8612**	9305	2133	3396	**2728**	3031
	93	Tell 'Ain el-Kerkh/II	4	6.00	7260	12798	**10334**	11166	2560	4075	**3274**	3637
	94	Tell Eli III	4	3.50	4235	7466	**6028**	6514	1493	2377	**1910**	2121
	95	Tell Labwé	4	3.50	4235	7466	**6028**	6514	1493	2377	**1910**	2121
	96	Tell Ramad II	4	2.60	3146	5546	**4478**	4839	1109	1766	**1419**	1576
	97	Tell Ras Shamra V B	4	3.00	3630	6399	**5167**	5583	1280	2037	**1636**	1819
	98	Tell Teo	4	3.50	4235	7466	**6028**	6514	1493	2377	**1910**	2121
	99	Tel Roim West IV	4	1.00	1210	2133	**1722**	1861	427	679	**545**	607
	100	Wadi Shu'eib	4	6.00	7260	12798	**10334**	11166	2560	4075	**3274**	3637
	101	Yiftah'el III (?)	4	1.50	1815	3200	**2584**	2792	640	1019	**818**	909
	102	'Ain Ghazal	5	8.00	-	-	**14144**	14888	3504	5026	**4265**	3810
	103	Basta (?)	5	7.00	-	-	**12376**	13027	3066	4397	**3731**	3333
	104	Beisamoun	5	7.00	-	-	**12376**	13027	3066	4397	**3731**	3333
	105	Es-Sayyeh	-	2.00	2266	6426	**3722**	3722	709	1498	**1089**	1089
	106	Wadi Fidan C	-	1.50	1700	4820	**2792**	2792	532	1123	**817**	817

Settlement population density coefficient method (SPDC)

Period	ID	Site name	Site type	Site extent (ha)	Population estimates			
					Site type			*Universal*
					Min	*Max*	**Mean**	
PPNA	1	Ain Darat	1	0.08	37	74	**52**	46
	2	Bir el-Maksur	1	0.20	93	185	**131**	115
	3	Borj Barajne	1	0.20	93	185	**131**	115
	4	Ein Suhun	1	0.30	140	278	**197**	173
	5	El Aoui Safa	1	0.20	93	185	**131**	115
	6	El Hemmeh	1	0.10	47	93	**66**	58
	7	Gesher	1	0.15	70	139	**98**	86
	8	Gilgal III	1	0.10	47	93	**66**	58
	9	Gilgal IV	1	0.10	47	93	**66**	58
	10	Hatoula	1	0.20	93	185	**131**	115
	11	Nahal Oren	1	0.05	23	46	**33**	29
	12	Zahrat Adh-Dhra' 2	1	0.20	93	185	**131**	115
	13	Dhra'	2	0.45	145	237	**191**	259
	14	Gilgal I	2	0.40	129	211	**170**	230
	15	Huzuq Musa	2	1.00	322	528	**425**	576
	16	Jericho	2	2.50	805	1319	**1062**	1440
	17	Netiv Hagdud	2	0.75	241	396	**319**	432
	18	Tell Aswad IA	2	1.00	322	528	**425**	576
EPPNB	19	Ain Abu Hudhud	1	0.20	93	185	**131**	115
	20	Ein Suhun	1	0.30	140	278	**197**	173
	21	El Hemmeh	1	0.10	47	93	**66**	58
	22	Motza VI	2	0.50	161	264	**212**	288
	23	Mujahiya	2	0.50	161	264	**212**	288
	24	Tell Aswad IB	2	1.00	322	528	**425**	576
	25	Horvat Galil	4	1.00	382	664	**569**	576
	26	Tell Qarassa	4	1.00	382	664	**569**	576
	27	Mishmar Ha'emeq	-	1.00	322	926	**576**	576
MPPNB	28	Adh-Dhaman I	1	0.20	93	185	**131**	115
	29	Ain Abu Nekheileh	1	0.12	56	111	**79**	69
	30	Beidha	1	0.20	93	185	**131**	115
	31	Jebel Arqa	1	0.20	93	185	**131**	115
	32	Jebel Rabigh	1	0.06	28	56	**39**	35
	33	Jebel Ragref	1	0.15	70	139	**98**	86
	34	Jebel Salaqa	1	0.10	47	93	**66**	58
	35	Shkārat Msaied	1	0.20	93	185	**131**	115
	36	Tell Eli IV	2	2.00	644	1055	**849**	1152
	37	Abu Gosh	3	0.25	92	148	**120**	144
	38	Wadi Hamarash I	3	0.50	185	297	**241**	288
	39	Ail IV	4	1.00	382	664	**569**	576
	40	'Ain Ghazal	4	4.00	1526	2654	**2278**	2304
	41	Beisamoun	4	5.00	1908	3318	**2847**	2880
	42	Ghwair I	4	1.325	506	879	**754**	763
	43	Horvat Galil	4	2.50	954	1659	**1424**	1440
	44	Jericho	4	4.00	1526	2654	**2278**	2304
	45	Khirbet Hammam	4	3.00	1145	1991	**1708**	1728
	46	Motza V	4	1.00	382	664	**569**	576
	47	Tell Abu es-Sawwan	4	3.00	1145	1991	**1708**	1728
	48	Tell Aswad II	4	5.00	1908	3318	**2847**	2880
	49	Tell Ghoraifé I	4	3.00	1145	1991	**1708**	1728
	50	Wadi Shu'eib	4	3.00	1145	1991	**1708**	1728
	51	Yiftah'el IV	4	1.00	382	664	**569**	576
	52	Mishmar Ha'emeq	-	0.50	161	463	**288**	288
	53	Munhata IV-VI	-	0.20	64	185	**115**	115
	54	Nahal Betzet I	-	0.50	161	463	**288**	288
	55	Tel Roim West V	-	0.50	161	463	**288**	288

Period	ID	Site name	Site type	Site extent (ha)	Population estimates			
					Site type			*Universal*
					Min	*Max*	**Mean**	
LPPNB	56	Beidha	3	0.30	111	178	**144**	173
	57	Ail IV	4	2.00	763	1327	**1139**	1152
	58	Ba'ja	4	1.35	515	896	**769**	778
	59	El Hemmeh	4	1.00	382	664	**569**	576
	60	Er-Rahib	4	3.00	1145	1991	**1708**	1728
	61	Jericho	4	4.00	1526	2654	**2278**	2304
	62	Moẕa Tahtit	4	2.00	763	1327	**1139**	1152
	63	Qminas	4	1.50	572	995	**854**	864
	64	Tell Aray	4	5.00	1908	3318	**2847**	2880
	65	Tell el-Ghafar I	4	1.50	572	995	**854**	864
	66	Tell Eli III	4	5.00	1908	3318	**2847**	2880
	67	Tell Ghoraifé II	4	5.00	1908	3318	**2847**	2880
	68	Tell Labwé	4	5.00	1908	3318	**2847**	2880
	69	Tell Rakan I	4	1.00	382	664	**569**	576
	70	Tell Ramad I	4	1.50	572	995	**854**	864
	71	Tell Ras Shamra V C	4	5.00	1908	3318	**2847**	2880
	72	Tel Tif'dan	4	3.00	1145	1991	**1708**	1728
	73	Wadi Badda	4	1.00	382	664	**569**	576
	74	Yiftah'el III	4	1.50	572	995	**854**	864
	75	'Ain Ghazal	5	10.00	4380	6040	**5210**	5760
	76	Ain Jamam	5	7.00	3066	4228	**3647**	4032
	77	Al-Baseet	5	7.50	3285	4530	**3908**	4320
	78	Basta	5	13.00	5694	7852	**6773**	7488
	79	Beisamoun	5	13.50	5913	8154	**7034**	7776
	80	Es-Sifiya	5	8.00	3504	4832	**4168**	4608
	81	Kharaysin	5	10.00	4380	6040	**5210**	5760
	82	Khirbet Hammam	5	7.00	3066	4228	**3647**	4032
	83	Tell Abu es-Sawwan	5	10.50	4599	6342	**5471**	6048
	84	Tell 'Ain el-Kerkh/II	5	16.00	7008	9664	**8336**	9216
	85	Wadi Shu'eib	5	8.00	3504	4832	**4168**	4608
	86	Aviel	-	3.00	966	2778	**1728**	1728
	87	Es-Sayyeh	-	3.50	1127	3241	**2016**	2016
PPNC	88	Atlit-Yam	4	3.00	1145	1991	**1708**	1728
	89	El Hemmeh	4	1.00	382	664	**569**	576
	90	Es-Sifiya	4	5.00	1908	3318	**2847**	2880
	91	Hagoshrim VI	4	3.50	1336	2323	**1993**	2016
	92	Tell Abu es-Sawwan	4	5.00	1908	3318	**2847**	2880
	93	Tell 'Ain el-Kerkh/II	4	6.00	2289	3981	**3417**	3456
	94	Tell Eli III	4	3.50	1336	2323	**1993**	2016
	95	Tell Labwé	4	3.50	1336	2323	**1993**	2016
	96	Tell Ramad II	4	2.60	992	1725	**1481**	1498
	97	Tell Ras Shamra V B	4	3.00	1145	1991	**1708**	1728
	98	Tell Teo	4	3.50	1336	2323	**1993**	2016
	99	Tel Roim West IV	4	1.00	382	664	**569**	576
	100	Wadi Shu'eib	4	6.00	2289	3981	**3417**	3456
	101	Yiftah'el III (?)	4	1.50	572	995	**854**	864
	102	'Ain Ghazal	5	8.00	3504	4832	**4168**	4608
	103	Basta (?)	5	7.00	3066	4228	**3647**	4032
	104	Beisamoun	5	7.00	3066	4228	**3647**	4032
	105	Es-Sayyeh	-	2.00	644	1852	**1152**	1152
	106	Wadi Fidan C	-	1.50	483	1389	**864**	864

Naroll's (1962) allometric growth formula (AGF1)

Period	ID	Site name	Site type	Site extent (ha)	Total built floor area (m^2) (A) Site type Minimum	Maximum	**Mean**	Universal	Population estimate (P) Site type Minimum	Maximum	**Mean**	Universal
PPNA	1	Ain Darat	1	0.08	236	432	286	324	30	102	**46**	29
	2	Bir el-Maksur	1	0.20	589	1079	716	810	89	304	**138**	86
	3	Borj Barajne	1	0.20	589	1079	716	810	89	304	**138**	86
	4	Ein Suhun	1	0.30	884	1619	1074	1215	145	493	**223**	140
	5	El Aoui Safa	1	0.20	589	1079	716	810	89	304	**138**	86
	6	El Hemmeh	1	0.10	295	540	358	405	39	134	**61**	38
	7	Gesher	1	0.15	442	810	537	607	64	216	**98**	61
	8	Gilgal III	1	0.10	295	540	358	405	39	134	**61**	38
	9	Gilgal IV	1	0.10	295	540	358	405	39	134	**61**	38
	10	Hatoula	1	0.20	589	1079	716	810	89	304	**138**	86
	11	Nahal Oren	1	0.05	147	270	179	202	17	59	**27**	17
	12	Zahrat Adh-Dhra' 2	1	0.20	589	1079	716	810	89	304	**138**	86
	13	Dhra'	2	0.45	1079	1800	1440	1822	125	239	**179**	226
	14	Gilgal I	2	0.40	959	1600	1280	1620	108	208	**156**	197
	15	Huzuq Musa	2	1.00	2398	4001	3200	4050	322	617	**463**	584
	16	Jericho	2	2.50	5995	10003	7999	10125	956	1832	**1375**	1733
	17	Netiv Hagdud	2	0.75	1799	3001	2400	3037	229	438	**329**	415
	18	Tell Aswad IA	2	1.00	2398	4001	3200	4050	322	617	**463**	584
EPPNB	19	Ain Abu Hudhud	1	0.20	589	1079	716	810	89	304	**138**	86
	20	Ein Suhun	1	0.30	884	1619	1074	1215	145	493	**223**	140
	21	El Hemmeh	1	0.10	295	540	358	405	39	134	**61**	38
	22	Motza VI	2	0.50	1199	2001	1600	2025	141	271	**203**	256
	23	Mujahiya	2	0.50	1199	2001	1600	2025	141	271	**203**	256
	24	Tell Aswad IB	2	1.00	2398	4001	3200	4050	322	617	**463**	584
	25	Horvat Galil	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	26	Tell Qarassa	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	27	Mishmar Ha'emeq	-	1.00	2398	6112	4050	4050	104	2386	**584**	584

Period	ID	Site name	Site type	Site extent (ha)	Total built floor area (m²) (A)				Population estimate (P)			
					Site type			*Universal*	*Site type*			*Universal*
					Minimum	*Maximum*	***Mean***		*Minimum*	*Maximum*	***Mean***	
MPPNB	28	Adh-Dhaman I	1	0.20	589	1079	716	810	89	304	**138**	86
	29	Ain Abu Nekheileh	1	0.12	354	648	430	486	49	166	**75**	47
	30	Beidha	1	0.20	589	1079	716	810	89	304	**138**	86
	31	Jebel Arqa	1	0.20	589	1079	716	810	89	304	**138**	86
	32	Jebel Rabigh	1	0.06	177	324	215	243	21	73	**33**	21
	33	Jebel Ragref	1	0.15	442	810	537	607	64	216	**98**	61
	34	Jebel Salaqa	1	0.10	295	540	358	405	39	134	**61**	38
	35	Shkārat Msaied	1	0.20	589	1079	716	810	89	304	**138**	86
	36	Tell Eli IV	2	2.00	4796	8002	6399	8100	734	1405	**1055**	1330
	37	Abu Gosh	3	0.25	914	1242	1078	1012	78	138	**104**	113
	38	Wadi Hamarash I	3	0.50	1828	2484	2156	2025	177	313	**238**	256
	39	Ail IV	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	40	'Ain Ghazal	4	4.00	11684	24448	19781	16199	959	4328	**2428**	3029
	41	Beisamoun	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	42	Ghwair I	4	1.325	3870	8098	6553	5366	258	1165	**654**	815
	43	Horvat Galil	4	2.50	7303	15280	12363	10125	549	2477	**1389**	1733
	44	Jericho	4	4.00	11684	24448	19781	16199	959	4328	**2428**	3029
	45	Khirbet Hammam	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	46	Motza V	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	47	Tell Abu es-Sawwan	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	48	Tell Aswad II	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	49	Tell Ghoraifé I	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	50	Wadi Shu'eib	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	51	Yiftah'el IV	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	52	Mishmar Ha'emeq	-	0.50	1199	3056	2025	2025	46	1047	**256**	256
	53	Munhata IV-VI	-	0.20	480	1222	810	810	15	353	**86**	86
	54	Nahal Betzet I	-	0.50	1199	3056	2025	2025	46	1047	**256**	256
	55	Tel Roim West V	-	0.50	1199	3056	2025	2025	46	1047	**256**	256

Period	ID	Site name	Site type	Site extent (ha)	Total built floor area (m^2) (A)				Population estimate (P)			
					Site type			*Universal*	*Site type*			*Universal*
					Minimum	*Maximum*	***Mean***		*Minimum*	*Maximum*	***Mean***	
LPPNB	56	Beidha	3	0.30	1097	1490	1293	1215	97	171	**130**	140
	57	Ail IV	4	2.00	5842	12224	9891	8100	421	1900	**1066**	1330
	58	Ba'ja	4	1.35	3943	8251	6676	5467	264	1191	**668**	834
	59	El Hemmeh	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	60	Er-Rahib	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	61	Jericho	4	4.00	11684	24448	19781	16199	959	4328	**2428**	3029
	62	Moẕa Tahtit	4	2.00	5842	12224	9891	8100	421	1900	**1066**	1330
	63	Qminas	4	1.50	4382	9168	7418	6075	299	1350	**757**	945
	64	Tell Aray	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	65	Tell el-Ghafar I	4	1.50	4382	9168	7418	6075	299	1350	**757**	945
	66	Tell Eli III	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	67	Tell Ghoraifé II	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	68	Tell Labwé	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	69	Tell Rakan I	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	70	Tell Ramad I	4	1.50	4382	9168	7418	6075	299	1350	**757**	945
	71	Tell Ras Shamra V C	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	72	Tel Tif'dan	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	73	Wadi Badda	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	74	Yiftah'el III	4	1.50	4382	9168	7418	6075	299	1350	**757**	945
	75	'Ain Ghazal	5	10.00	-	-	53640	40499	4163	5759	**4849**	8995
	76	Ain Jamam	5	7.00	-	-	37548	28349	2725	3770	**3175**	5888
	77	Al-Baseet	5	7.50	-	-	40230	30374	2958	4092	**3446**	6391
	78	Basta	5	13.00	-	-	69732	52648	5685	7864	**6622**	12283
	79	Beisamoun	5	13.50	-	-	72414	54673	5945	8225	**6926**	12846
	80	Es-Sifiya	5	8.00	-	-	42912	32399	3194	4418	**3720**	6900
	81	Kharaysin	5	10.00	-	-	53640	40499	4163	5759	**4849**	8995
	82	Khirbet Hammam	5	7.00	-	-	37548	28349	2725	3770	**3175**	5888
	83	Tell Abu es-Sawwan	5	10.50	-	-	56322	42524	4411	6102	**5138**	9531
	84	Tell 'Ain el-Kerkh/II	5	16.00	-	-	85824	64798	7275	10064	**8474**	15719
	85	Wadi Shu'eib	5	8.00	-	-	42912	32399	3194	4418	**3720**	6900
	86	Aviel	-	3.00	7194	18336	12150	12150	383	8798	**2153**	2153
	87	Es-Sayyeh	-	3.50	8393	21392	14175	14175	460	10565	**2585**	2585

Period	ID	Site name	Site type	Site extent (ha)	Total built floor area (m^2) (A)				Population estimate (P)			
					Site type			*Universal*	*Site type*			*Universal*
					Minimum	*Maximum*	***Mean***		*Minimum*	*Maximum*	***Mean***	
PPNC	88	Atlit-Yam	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	89	El Hemmeh	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	90	Es-Sifiya	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	91	Hagoshrim VI	4	3.50	10224	21392	17309	14175	819	3694	**2072**	2585
	92	Tell Abu es-Sawwan	4	5.00	14605	30560	24727	20249	1251	5642	**3164**	3949
	93	Tell 'Ain el-Kerkh/II	4	6.00	17526	36672	29672	24299	1553	7006	**3929**	4903
	94	Tell Eli III	4	3.50	10224	21392	17309	14175	819	3694	**2072**	2585
	95	Tell Labwé	4	3.50	10224	21392	17309	14175	819	3694	**2072**	2585
	96	Tell Ramad II	4	2.60	7595	15891	12858	10530	575	2595	**1455**	1816
	97	Tell Ras Shamra V B	4	3.00	8763	18336	14836	12150	682	3076	**1725**	2153
	98	Tell Teo	4	3.50	10224	21392	17309	14175	819	3694	**2072**	2585
	99	Tel Roim West IV	4	1.00	2921	6112	4945	4050	185	834	**468**	584
	100	Wadi Shu'eib	4	6.00	17526	36672	29672	24299	1553	7006	**3929**	4903
	101	Yiftah'el III (?)	4	1.50	4382	9168	7418	6075	299	1350	**757**	945
	102	'Ain Ghazal	5	8.00	-	-	42912	32399	3194	4418	**3720**	6900
	103	Basta (?)	5	7.00	-	-	37548	28349	2725	3770	**3175**	5888
	104	Beisamoun	5	7.00	-	-	37548	28349	2725	3770	**3175**	5888
	105	Es-Sayyeh	-	2.00	4796	12224	8100	8100	237	5435	**1330**	1330
	106	Wadi Fidan C	-	1.50	3597	9168	6075	6075	168	3862	**945**	945

Wiessner's (1974) allometric growth formula (AGF2)

Period	ID	Site name	Site type	Site extent (ha)	Site extent (m^2) (A)	Population estimate (P) Site type Min	Max	**Mean**	Universal
PPNA	1	Ain Darat	1	0.08	800	36	70	**47**	40
	2	Bir el-Maksur	1	0.20	2000	90	176	**119**	100
	3	Borj Barajne	1	0.20	2000	90	176	**119**	100
	4	Ein Suhun	1	0.30	3000	136	264	**178**	149
	5	El Aoui Safa	1	0.20	2000	90	176	**119**	100
	6	El Hemmeh	1	0.10	1000	45	88	**59**	50
	7	Gesher	1	0.15	1500	68	132	**89**	75
	8	Gilgal III	1	0.10	1000	45	88	**59**	50
	9	Gilgal IV	1	0.10	1000	45	88	**59**	50
	10	Hatoula	1	0.20	2000	90	176	**119**	100
	11	Nahal Oren	1	0.05	500	23	44	**30**	25
	12	Zahrat Adh-Dhra' 2	1	0.20	2000	90	176	**119**	100
	13	Dhra'	2	0.45	4500	143	223	**174**	224
	14	Gilgal I	2	0.40	4000	127	198	**155**	199
	15	Huzuq Musa	2	1.00	10000	318	495	**387**	498
	16	Jericho	2	2.50	25000	795	1238	**968**	1244
	17	Netiv Hagdud	2	0.75	7500	238	372	**290**	373
	18	Tell Aswad IA	2	1.00	10000	318	495	**387**	498
EPPNB	19	Ain Abu Hudhud	1	0.20	2000	90	176	**119**	100
	20	Ein Suhun	1	0.30	3000	136	264	**178**	149
	21	El Hemmeh	1	0.10	1000	45	88	**59**	50
	22	Motza VI	2	0.50	5000	159	248	**194**	249
	23	Mujahiya	2	0.50	5000	159	248	**194**	249
	24	Tell Aswad IB	2	1.00	10000	318	495	**387**	498
	25	Horvat Galil	4	1.00	10000	365	638	**456**	498
	26	Tell Qarassa	4	1.00	10000	365	638	**456**	498
	27	Mishmar Ha'emeq	-	1.00	10000	317	877	**498**	498
MPPNB	28	Adh-Dhaman I	1	0.20	2000	90	176	**119**	100
	29	Ain Abu Nekheileh	1	0.12	1200	54	105	**71**	60
	30	Beidha	1	0.20	2000	90	176	**119**	100
	31	Jebel Arqa	1	0.20	2000	90	176	**119**	100
	32	Jebel Rabigh	1	0.06	600	27	53	**36**	30
	33	Jebel Ragref	1	0.15	1500	68	132	**89**	75
	34	Jebel Salaqa	1	0.10	1000	45	88	**59**	50
	35	Shkārat Msaied	1	0.20	2000	90	176	**119**	100
	36	Tell Eli IV	2	2.00	20000	636	991	**774**	995
	37	Abu Gosh	3	0.25	2500	88	142	**109**	124
	38	Wadi Hamarash I	3	0.50	5000	177	284	**218**	249
	39	Ail IV	4	1.00	10000	365	638	**456**	498
	40	'Ain Ghazal	4	4.00	40000	1459	2551	**1826**	1990
	41	Beisamoun	4	5.00	50000	1823	3189	**2282**	2488
	42	Ghwair I	4	1.325	13250	483	845	**605**	659
	43	Horvat Galil	4	2.50	25000	912	1594	**1141**	1244
	44	Jericho	4	4.00	40000	1459	2551	**1826**	1990
	45	Khirbet Hammam	4	3.00	30000	1094	1913	**1369**	1493
	46	Motza V	4	1.00	10000	365	638	**456**	498
	47	Tell Abu es-Sawwan	4	3.00	30000	1094	1913	**1369**	1493
	48	Tell Aswad II	4	5.00	50000	1823	3189	**2282**	2488
	49	Tell Ghoraifé I	4	3.00	30000	1094	1913	**1369**	1493
	50	Wadi Shu'eib	4	3.00	30000	1094	1913	**1369**	1493
	51	Yiftah'el IV	4	1.00	10000	365	638	**456**	498
	52	Mishmar Ha'emeq	-	0.50	5000	159	439	**249**	249
	53	Munhata IV-VI	-	0.20	2000	63	175	**100**	100
	54	Nahal Betzet I	-	0.50	5000	159	439	**249**	249
	55	Tel Roim West V	-	0.50	5000	159	439	**249**	249

Period	ID	Site name	Site type	Site extent (ha)	Site extent (m^2) (A)	Population estimate (P) Site type *Min*	*Max*	***Mean***	*Universal*
LPPNB	56	Beidha	3	0.30	3000	106	170	**131**	149
	57	Ail IV	4	2.00	20000	729	1276	**913**	995
	58	Ba'ja	4	1.35	13500	492	861	**616**	672
	59	El Hemmeh	4	1.00	10000	365	638	**456**	498
	60	Er-Rahib	4	3.00	30000	1094	1913	**1369**	1493
	61	Jericho	4	4.00	40000	1459	2551	**1826**	1990
	62	Moẕa Tahtit	4	2.00	20000	729	1276	**913**	995
	63	Qminas	4	1.50	15000	547	957	**685**	746
	64	Tell Aray	4	5.00	50000	1823	3189	**2282**	2488
	65	Tell el-Ghafar I	4	1.50	15000	547	957	**685**	746
	66	Tell Eli III	4	5.00	50000	1823	3189	**2282**	2488
	67	Tell Ghoraifé II	4	5.00	50000	1823	3189	**2282**	2488
	68	Tell Labwé	4	5.00	50000	1823	3189	**2282**	2488
	69	Tell Rakan I	4	1.00	10000	365	638	**456**	498
	70	Tell Ramad I	4	1.50	15000	547	957	**685**	746
	71	Tell Ras Shamra V C	4	5.00	50000	1823	3189	**2282**	2488
	72	Tel Tif'dan	4	3.00	30000	1094	1913	**1369**	1493
	73	Wadi Badda	4	1.00	10000	365	638	**456**	498
	74	Yiftah'el III	4	1.50	15000	547	957	**685**	746
	75	'Ain Ghazal	5	10.00	100000	4386	6024	**5076**	4975
	76	Ain Jamam	5	7.00	70000	3070	4217	**3553**	3483
	77	Al-Baseet	5	7.50	75000	3289	4518	**3807**	3731
	78	Basta	5	13.00	130000	5702	7831	**6599**	6468
	79	Beisamoun	5	13.50	135000	5921	8133	**6853**	6716
	80	Es-Sifiya	5	8.00	80000	3509	4819	**4061**	3980
	81	Kharaysin	5	10.00	100000	4386	6024	**5076**	4975
	82	Khirbet Hammam	5	7.00	70000	3070	4217	**3553**	3483
	83	Tell Abu es-Sawwan	5	10.50	105000	4605	6325	**5330**	5224
	84	Tell 'Ain el-Kerkh/II	5	16.00	160000	7018	9639	**8122**	7960
	85	Wadi Shu'eib	5	8.00	80000	3509	4819	**4061**	3980
	86	Aviel	-	3.00	30000	952	2632	**1493**	1493
	87	Es-Sayyeh	-	3.50	35000	1111	3070	**1741**	1741
PPNC	88	Atlit-Yam	4	3.00	30000	1094	1913	**1369**	1493
	89	El Hemmeh	4	1.00	10000	365	638	**456**	498
	90	Es-Sifiya	4	5.00	50000	1823	3189	**2282**	2488
	91	Hagoshrim VI	4	3.50	35000	1276	2232	**1597**	1741
	92	Tell Abu es-Sawwan	4	5.00	50000	1823	3189	**2282**	2488
	93	Tell 'Ain el-Kerkh/II	4	6.00	60000	2188	3827	**2738**	2985
	94	Tell Eli III	4	3.50	35000	1276	2232	**1597**	1741
	95	Tell Labwé	4	3.50	35000	1276	2232	**1597**	1741
	96	Tell Ramad II	4	2.60	26000	948	1658	**1187**	1294
	97	Tell Ras Shamra V B	4	3.00	30000	1094	1913	**1369**	1493
	98	Tell Teo	4	3.50	35000	1276	2232	**1597**	1741
	99	Tel Roim West IV	4	1.00	10000	365	638	**456**	498
	100	Wadi Shu'eib	4	6.00	60000	2188	3827	**2738**	2985
	101	Yiftah'el III (?)	4	1.50	15000	547	957	**685**	746
	102	'Ain Ghazal	5	8.00	80000	3509	4819	**4061**	3980
	103	Basta (?)	5	7.00	70000	3070	4217	**3553**	3483
	104	Beisamoun	5	7.00	70000	3070	4217	**3553**	3483
	105	Es-Sayyeh	-	2.00	20000	635	1754	**995**	995
	106	Wadi Fidan C	-	1.50	15000	476	1316	**746**	746

Appendix E.3: Statistical tests for systematic methodologies

Paired-samples t test and Wilcoxon signed-rank test

Process in SPSS

Paired-Samples T Test

1. Go to ‘Analyse’ – ‘Compare Means’ – ‘Paired-Samples T Test’
2. Select variables for ‘Paired Variables’ (i.e. variables for comparison)
3. Assess output: p value < .05 indicates significant difference

Wilcoxon Signed-Rank Test

1. Go to ‘Analyse’ – ‘Nonparametric Tests’ – ‘Legacy Dialogs’ – 2 Related Samples’
2. Select variables for ‘Test Pairs’ (i.e. variables for comparison)
3. Select ‘Wilcoxon’ ‘Test Type’
4. Assess output: p value < .05 indicates significant difference

Regression analysis (Pearson’s correlation coefficient)

Process in SPSS

1. Go to ‘Analyse’ – ‘Regression’ – ‘Linear’
2. Select ‘Independent’ variable (i.e. a variable which may be impacted by other variables: the degree of difference between micro-level and systematic estimates)
3. Select ‘Dependent’ variable/s (i.e. variables which might impact the independent variable: structural density)
4. Select ‘Model fit’ and ‘Descriptives’ in ‘Statistics’
5. Select ‘Include constant in equation’ in ‘Options’
6. Assess outputs:
   - Pearson’s correlation coefficient (*r*)
   - *p* value < .05 indicates significant correlation
   - r^2 value: proportion of variation in independent variable due to variations in dependent variable

Appendix E.4: Data used to derive potential group size thresholds

Pre-Pottery Neolithic A (PPNA)

Site name	Population estimate	Potential evidence for developments in:				
		Subsistence strategies		**Mechanisms for social cohesion (and social complexity)**		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
Nahal Oren	25-45	Harvesting of wild plants	Hunting of gazelle, pig, goat, deer	Figurines	Some dwelling based consumption and processing; communal storage, processing and cooking	
Gilgal IV	40-90			Figurines		
El Hemmeh	70-100	Harvesting of wild barley		Figurine; potential ritual structure	Some dwelling based storage, processing, cooking	
Bir el-Maksur	80-190	Cultivation of wild plants; conditions not ideal for natural plant growth	Hunting of gazelle, boar, cape hare and fox	Secondary burial with grave goods		
Zahrat Adh-Dhra' 2	80-190	Major food plants from highlands and/or cultivated on site; conditions not ideal for natural plant growth		Figurine; skull removal; a multiple burial		
Ein Suhun	130-280					
Dhra'	130-300	Potential deliberate cultivation of wild plants		Human figurine; one phallus	Communal storage	
Gilgal I	160-290	Cultivation of wild barley	Hunting of gazelle and birds	Figurines; ritual building; miniature grinding tools	Communal storage and cooking; dwelling-based production, processing and consumption	
Netiv Hagdud	220-270	Cultivation of wild barley and lentils		Burials; adult skull removal; symbolic items; figurines	Communal and residential storage; dwelling-based processing and consumption	
Huzuq Musa	300-660					
Jericho	740-1650			Burials	Annexes on dwellings; communal storage; cooperative labour force	

Site name	Population estimate	Potential evidence for developments in:			
		Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
Nahal Oren	25-45			Workshops	
Gilgal IV	40-90				
El Hemmeh	70-100				
Bir el-Maksur	80-190			Burnt clay lumps interpreted as first known potential lime production	
Zahrat Adh-Dhra' 2	80-190		Items of personal adornment	Potential workshop for incised pebbles; stone and shell beads	Incised pebbles/stones
Ein Suhun	130-280				Incised pebble
Dhra'	130-300				
Gilgal I	160-290		Items of personal adornment	Stone vessels, tools and figurines	
Netiv Hagdud	220-270		Items of personal adornment	Decorative items; figurines	Incised pebbles
Huzuq Musa	300-660			Bead production	
Jericho	740-1650		Items of personal adornment; organised labour force		

Site name	References
Nahal Oren	Stekelis and Yizraely 1963, Noy *et al.* 1973, Twiss 2001; Kuijt and Chesson 2005; Nadel *et al.* 2012
Gilgal IV	Twiss 2001
El Hemmeh	Wright 2000; Makarewicz and Austin 2006; Makarewicz *et al.* 2006; Makarewicz and Rose 2011; White and Makarewicz 2012; White 2013
Bir el-Maksur	Malinksy-Buller *et al.* 2013
Zahrat Adh-Dhra' 2	Edwards *et al.* 2004; Edwards 2007; Edwards and House 2007
Ein Suhun	Nadel *et al.* 1999
Dhra'	Kuijt and Mahasneh 1998; Kuijt 2001; Finlayson *et al.* 2003; Kuijt and Chesson 2005
Gilgal I	Noy 1989; Kuijt and Chesson 2005 ;Rosenberg 2008; Bar-Yosef *et al.* 2010a; 2010b; Weiss and Zohary 2011
Netiv Hagdud	Bar-Yosef *et al.* 1980; 1991; Bar-Yosef and Gopher 1997; Weiss and Zohary 2011
Huzuq Musa	Nadel and Rosenberg 2013; Groman-Yaroslavski *et al.* 2014
Jericho	Kenyon 1956; Kenyon 1981; Kuijt and Finlayson 2009

Early Pre-Pottery Neolithic B (EPPNB)

Site name	Population estimate	Potential evidence for developments in:				
		Subsistence strategies		Mechanisms for social cohesion (and social complexity)		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
El Hemmeh	70-100			Mortuary installations beneath floor of structure; one covered with lime or gypsum plaster	Large bin in one structure	
Motza VI	150-330		Hunting of gazelle, fox, aurochs, wild boar and goat	Nine graves - primary, flexed burials; some variety; associated with plaster; subfloor and courtyard burials; skull removal; stone and clay figurines; stone figurnine broken and used as a pendant		
Mujahiya	150-330	Intensive harvesting of wild plants (sickle blades and many grinding and pounding tools)	Hunting of gazelle, bovids, goat and pig	Yellow and red ochre		
Mishmar Ha'emeq	320-750		Hunting of cattle, then gazelle, wild boar and goat	Burial ground and ritual building		
Tell Aswad IB	300-660	Domesticated (?) emmer and barley		Primary and secondary burials, individual and collective burials, skull removal and plastering; sub-floor and courtyard burials, and grave goods; platform burials		
Horvat Galil	370-680			Burials; beneath dwelling floors		
Tell Qarassa	370-680		Hunting of goat, gazelle, pig, cattle and deer	24 individuals; primary and secondary; associated with structures; individual and collective; skull removal; clay figurines and ornamental objects		

Site name	Population estimate	Potential evidence for developments in: Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
El Hemmeh	70-100				
Motza VI	150-330		Items of personal adornment; variable mortuary treatment	Lime plaster floors; naviform technology and Helwan points; blade cache (58 elongated blades)	Incised bone
Mujahiya	150-330			Very small quantities of plaster-like material; naviform core technology	
Mishmar Ha'emeq	320-750				
Tell Aswad IB	300-660		Variable mortuary treatment		
Horvat Galil	370-680			Plasterd floors	
Tell Qarassa	370-680		Items of personal adornment; different grave goods and burials	Figurines; items of personal adornment	Mud tokens

Site name	References
El Hemmeh	Makarewicz and Rose 2011
Motza VI	Khalaily *et al.* 2007
Mujahiya	Gopher 1990
Mishmar Ha'emeq	Bocquentin *et al.* 2011
Tell Aswad IB	Stordeur and Jamous 2009; Tanno and Willcox 2012; Chamel 2014
Horvat Galil	Hershkovitz and Gopher 1988
Tell Qarassa	Ibañez *et al.* 2010

Middle Pre-Pottery Neolithic B (MPPNB)

Site name	Population estimate	Potential evidence for developments in:				
		Subsistence strategies		**Mechanisms for social cohesion (and social complexity)**		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
Jebel Rabigh	30-60					
Jebel Salaqa	40-90					
Jebel Ragref	60-140					
Munhata IV-VI	60-150			Anthropomorphic figurines		
Beidha (A2)	80-120	Domesticated barley and emmer	Culturally controlled wild goats	Ritual structures; mortuary practices; clay anthropomorphic figurines	Dwelling based production, processing and consumption; communal and dwelling based cooking; more formalised and resticted access to dwellings	Possible neighbourhoods
Shkārat Msaied	80-150	Cultivation of (wild?) plants	Possibly domesticated goat and sheep	Central ritual structures; mortuary building; 15 burials; feasting; grave goods; possible household-based ritual	Dwelling-based storage, processing, consumption, cooking; possible communal processing; possible household-based ritual	Possible neighbourhoods
Jebel Arqa	80-190					
Abu Gosh	90-150		Management of wild goats	Burials	Dwelling-based storage, production, processing and consumption	
'Ain Abu Nekheileh	90-150	Barley cultivation; 300+ grinding implements/sickles	Potential goat and sheep pastoralism	Items of personal adornment	Residential storage, production, processing; possible communal consumption	
Wadi Hamarash I	150-220	Cultivation of einkorn, emmer, barley; 900+ ground stone tools	(Domesticated?) goat and sheep	Large, central communal/ritual building with symbolic items; incised stones; figurine	Dwelling-based storage, production, processing and consumption	Possible neighbourhoods
Mishmar Ha'emeq	160-370		Hunting (management?) cattle, gazelle, boar and goat	Large paved flagstone ritual structure with burial ground; grave goods		
Yiftah'el IV	370-680	Domesticated lentil	Hunting (management?) of gazelle, goat and boar	Burials; skull removal and plastering; burials beneath dwelling floors; primary and secondary burials	Dwelling-based storage, production, processing and consumption	
Ghwair I	400-610	Cultivation of (domesticated?) barely, emmer, einkorn, pea	Domesticated goats	Burials; skull removal and plastering; figurines; infant burial with grave goods	Dwelling-based storage, production, processing and consumption	Possible neighbourhoods

Site name	Population estimate	Potential evidence for developments in:				
		Subsistence strategies		Mechanisms for social cohesion (and social complexity)		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
Tell Ghoraifé I	1090-2040		Domesticated (?) sheep			
Wadi Shu'eib	1090-2040		Domesticated (?) sheep and goat	Burials; skull removal and plastering		
'Ain Ghazal	1460-2720	Possible domesticated chickpea	Domesticated goat and sheep; pastoralism for meat and milk	Ritual structures; burials; skull removal and plastering; cache of anthropomorphic and zoomorphic figurines		
Jericho	1460-2720	Domesticated plants; possible domesticated chickpea and flax		Burials; skull removal and plastering; anthropomorphic and zoomorphic figurines		Possible neighbourhoods
Beisamoun	1820-3400			Burials; skull removal and plastering		
Tell Aswad II	1820-3400	Domesticated barley, fig cultivation	Domesticated goat, sheep, pig and cattle; pastoralism for meat and milk	Burials; skull removal and plastering; anthropomorphic and zoomorphic figurines		

Site name	Population estimate	Potential evidence for developments in: Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
Jebel Rabigh	30-60			Amazonite bead workshops	
Jebel Salaqa	40-90			Amazonite bead workshops	
Jebel Ragref	60-140			Amazonite bead workshops	
Munhata IV-VI	60-150			Bidirectional blade technology	
Beidha (A2)	80-120			Plaster	
Shkārat Msaied	80-150		Items of personal adornment; vairable grave goods; differeng strucutral associations	Plaster; bead workshops; naviform core technology; worked shell, bone, etc.	Incised pebbles, stones and slabs
Jebel Arqa	80-190			Amazonite bead workshops	
Abu Gosh	90-150				
‘Ain Abu Nekheileh	90-150		Items of personal adornment	Naviform core technology	
Wadi Hamarash I	150-220	Two-storey building	Items of personal adornment	Small scale production of stone, shell and bone objects and jewellery; specialist activity areas	Incised stones
Mishmar Ha’emeq	160-370			Bidirectional blade technology	
Yiftah'el IV	370-680			Plaster use and production; naviform core technology; flint knapping workshops	
Ghwair I	400-610	Two-storey building	Clay tokens; incised stones; mother of pearl; variable grave goods	Plasers, tools; symbolic items	Clay tokens; incised stones; large public staircase and plaza
Tell Ghoraifé I	1090-2040				
Wadi Shu'eib	1090-2040		Items of personal adornment	Plaster; beads; pendant	
'Ain Ghazal	1460-2720	Potential retaining wall	Well-established ritual - structures; variable grave goods	Plaster	
Jericho	1460-2720			Plaster	
Beisamoun	1820-3400			Plaster	
Tell Aswad II	1820-3400			Plaster	

Site name	References
Jebel Rabigh	Fabiano *et al.* 2004
Jebel Salaqa	Fabiano *et al.* 2004
Jebel Ragref	Berna 1995
Munhata IV-VI	Perrot 1966
Beidha (A2)	Byrd 2005a; Colledge and Conolly 2007; Martin and Edwards 2013
Shkarat Msaied	Byrd 1994; Hermansen and Hoffman Jensen 2002; Bartl *et al.* 2006; Jensen *et al.* 2005; Hermansen *et al.* 2006; Edwards 2007; Kinzel 2013
Jebel Arqa	Fabiano *et al.* 2004
Abu Gosh	Grindell 1998; Ducos and Horwitz 2003; Martin and Edwards 2013
Ain Abu Nekheileh	Henry *et al.* 2002; 2003; Fabiano *et al.* 2004; Henry and Albert 2004
Wadi Hamarash I	Donta 2013; Gkotsinas and Karathanou 2013; Sampson 2013; Tampakopoulou 2013
Mishmar Ha'emeq	Bocquentin *et al.* 2011
Yiftah'el IV	Barzilai and Getzov 2008; Kuijt 2008b; Weiss and Zohary 2011
Ghwair I	Simmons and Najjar 2006; Kuijt 2008b
Tell Ghoraifé I	Van Zeist and Bakker-Heeres 1985; Martin and Edwards 2013
Wadi Shu'eib	Simmons *et al.* 2001; Kuijt 2008b
'Ain Ghazal	Rollefson *et al.* 1993; Kuijt and Chesson 2005; Kuijt 2008b; Weiss and Zohary 2011; Martin and Edwards 2013
Jericho	Kuijt and Chesson 2005; Colledge and Conolly 2007; Kuijt 2008b; Weiss and Zohary 2011
Beisamoun	Kuijt and Chesson 2005; Kuijt 2008b; Bocquentin 2011
Tell Aswad II	Stordur 2003; Colledge and Conolly 2007; Stordeur and Jamous 2009; Kuijt 2008b; Weiss and Zohary 2011; Makarewicz 2013a

Late Pre-Pottery Neolithic B (LPPNB)

Site name	Population estimate	Potential evidence for developments in:				
		Subsistence strategies		**Mechanisms for social cohesion (and social complexity)**		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
Beidha (C2)	140-220	Domesticated barley and emmer	Domesticated goats	Large non-residential structure in centre of site; circular ritual structures nearby	Dwelling-based storage, production, processing and consumption	Possible neighbourhoods
Wadi Badda	370-680					
El Hemmeh	530-800	Cultivation of wild barley; domesticated emmer and small-seeded legumes	Domesticated goat and sheep; pastoralism for meat and milk production	Anthropomorphic figurine; burial with grave goods	Dwelling-based storage, production, processing and consumption; possible household inherited agricultural knowledge	
Yiftah'el III	550-1020	Domesticated lentil		Primary and secondary burials; plastered skulls; two large communal buildings; red paint	Dwelling-based storage, cooking and processing	
Ba'ja	580-610	Probable domesticated emmer	Domesticated goat and sheep	Anthropomorphic figurines; burials; grave goods; collective burials; red pigment on bones; painting on chamber wall; ritual related imagery	Dwelling-based storage, production, processing and consumption; household based production of sandstone rings	Possible neighbourhoods
Motza Tahtit	730-1360			Burial with fox mandible; burial beneath building; figurine; ritual structure		
Tel Tif'dan	1090-2040		Domesticated goats; culturally controlled sheep and cattle; possile cattle domestication; pastoralism for meat and some milk production	Many figurines; wall niches with infant bones		
Tell Labwé	1820-3400	Domesticated lentils, emmer and barley	Domestic goat, sheep and cattle(?)	Burials beneath dwelling floors; secondary burial; multiple burial in pit; decorated grave walls; red pigment		
Tell Ras Shamra V C	1820-3400		Pastoralism for meat and milk			

Site name	**Population estimate**	**Potential evidence for developments in:**				
		Subsistence strategies		**Mechanisms for social cohesion (and social complexity)**		
		Farming/agriculture	*Hunting/pastoralism*	*Ritual*	*Communal vs house-based activities*	*Community sectoring*
‘Ain Jamam	3070-4400		Domesticated goat and sheep for meat and milk production		Dwelling-based storage, cooking and processing	
Al Basit	3290-4710					
Es Sifiya	3500-5030	Domesticated(?) barley and emmer	Domesticated goat and sheep; also hunted; pastoralism for meat and milk production	Skull removal and caching; geometric and zoomorphic figurines	Dwelling-based storage, cooking and processing	
‘Ain Ghazal	4380-6280		Domesticated goat, sheep and cattle; pastoralism for meat and milk production	Skull removal; burials; ritual buildings; clay anthropomorphic figurine		
Basta	5690-7850		Culling of wild goats; domesticated goat, sheep and cattle; mixture of domesticated and wild cattle	Zoomorphic figurines	Dwelling-based storage, cooking and processing	Possible neighbourhoods
Beisamoun	5910-8480			Skull removal	Dwelling-based storage, cooking and processing	Possible neighbourhoods
Tell Ain el-Kerkh/II	7010-10050	Large scale cereal cultivation		Infant burials		

Site name	**Population estimate**	**Potential evidence for developments in:**			
		Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
Beidha (C2)	140-220	Heat treatment for lithic production; two storey buildings	Central management of resources; items of personal adornment; dwellings of different layout and size	Plaster; bone tool and bead production	
Wadi Badda	370-680	Water management: barrage around 15-20m long across the wadi, below the site			

Site name	Population estimate	Potential evidence for developments in: Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
El Hemmeh	530-800	Possible intentional irrigation; sub-floor channels (water or air?)	Items of personal adornment; different architectural forms and displays of wealth; variable grave goods	Bead workshops; centre for agricultural activities	
Yiftah'el III	550-1020			Plaster; naviform core technology; flint knapping workshops	
Ba'ja	580-610	Possible harvesting of rain water/intentional irrigation	Items of personal adornment; different architectural forms; variable grave goods	Jewelry and tools; sandstone ring production centre	
Motza Tahtit	730-1360		Variable grave goods	Lime kilns and ash pits; plaster	
Tel Tif'dan	1090-2040		Items of personal adornment	Bead production site; figurines: animal, human, animals with flint blades, small tokens; plaster not common	Tokens
Tell Labwé	1820-3400		Items of personal adornment; variable skeletal treatment and grave goods	Plaster; lime plaster floors green stone and shell beads	
Tell Ras Shamra V C	1820-3400				
‘Ain Jamam	3070-4400	Subfloor channels (water or air?); two storey buildings	Corporate organization; differentiation in labor, subsistence, household and communal tasks	Plaster; drills for bead production	
Al Basit	3290-4710			Bead production workshops	
Es Sifiya	3500-5030	Heat treatment for lithic production; subfloor channels (water or air?); terraced walls	Corporate organization; differentiation in labor, subsistence, household and communal tasks	Clay geometric objects and human figurines; plaster; wood-working workshops: axes, adzes and chisels 18% of assemblage; human figurine made of white quartz crystal with red ochre incised eyes, neck and head	Clay geometric objects
‘Ain Ghazal	4380-6280	Apsidal and circular ritual buildings; retaining wall; heat treatment for lithic production; two storey buildings	Items of personal adornment corporate organization; differentiation in labor, subsistence, household and communal tasks	Plaster; bracelets	
Basta	5690-7850	Heat treatment for lithic production; subfloor channels (water or air?); two storey buildings	Corporate organization; differentiation in labor, subsistence, household and communal tasks		Grooved stones; incised tokens

Site name	Population estimate	Potential evidence for developments in: Social complexity			
		Innovative ideas	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
Beisamoun	5910-8480		Corporate organization; differentiation in labor, subsistence, household and communal tasks		
Tell Ain el-Kerkh/II	7010-10050		Corporate organization; differentiation in labor, subsistence, household and communal tasks	Uni-directional blade manufacture for sickle production	

Site name	References
Beidha (C2)	Mahasneh 1996; Byrd 2005a; Martin and Edwards 2013
Wadi Badda	Fujii 2007
El Hemmeh	Wright 2000; Makarewicz and Austin 2006; Makarewicz *et al.* 2006; Makarewicz and Rose 2011; White and Makarewicz 2012; Makarewicz 2013; White 2013
Yiftah'el III	Barzilai and Getzov 2008; Weiss and Zohary 2011
Ba'ja	Horwitz and Ducos 2005; Kinzel 2013; Makarewicz 2013; Martin and Edwards 2013
Moẕa Tahtit	Mizrahi 2015; Lazaridis *et al.* 2016
Tel Tif'dan	Twisss 2007; Bennallack 2012; Makarewicz 2013
Tell Labwé	Ibañez *et al.* 2012; Khalidi *et al.* 2013
Tell Ras Shamra V C	Makarewicz 2013
‘Ain Jamam	Mahasneh 1996; Kuijt 2000; Gebel 2002a,b; Rollefson 2002; Makarewicz 2009; 2013
Al Basit	Rollefson 2002
Es Sifiya	Mahasneh 1996; Mahasneh and Gebel 1998; Gebel 2002a,b; Kuijt and Chesson 2005; Makarewicz 2013
‘Ain Ghazal	Mahasneh 1996; Rollefson and Kafafi 1997; Kuijt 2000; Gebel 2002a,b; Horwitz and Ducos 2005; Kuijt and Chesson 2005; Makarewicz 2013
Basta	Hermansen and Gebel 1996; Mahasneh 1996; Kuijt 2000; Gebel 2002a,b; Ducos and Horwitz 2003; Horwitz and Ducos 2005; Kuijt and Chesson 2005; Martin and Edwards 2013
Beisamoun	Gebel 2002a,b; Bocquentin 2011
Tell Ain el-Kerkh/II	Gebel 2002a,b; Arimura 2011; Tsuneki 2012

Pre-Pottery Neolithic C (PPNC)

Site name	Population estimate	Potential evidence for developments in: Subsistence strategies: *Farming/agriculture*	*Hunting/pastoralism*	Mechanisms for social cohesion (and social complexity): *Ritual*	*Communal vs house-based activities*	*Community sectoring*
Wadi Fidan C	480-1120	Domesticated barley, einkorn	Domesticated goat and sheep			
Tell Ramad II	950-1770	Domesticated plants chickpea and flax				
Atlit-Yam	1090-2040	Domesticated emmer and naked wheat, cereals, flax, legumes; weeds	Domesticated goat, sheep, pig, dogs, cat and early domesticted cattle; major concentrations of fish bones	90+ burials; primary and secondary; circular ritual installations		Possible neighbourhoods; massive wall segmening community
Hagoshrim VI	1280-2380		High pig bone frequencies - possible domestication			
Tell Labwé	1280-2380	Domesticated lentils, emmer and barley	Domestic goat, sheep and cattle(?)	Burials beneath dwelling floors; secondary burial; multiple burial in pit; decorated grave walls; red pigment		
Tell Teo	1280-2380		High cattle bone frequencies - possible domestication			
‘Ain Ghazal	3500-5030		High pig bone frequencies - possible domestication	Ritual buildings; burials with intact skulls; human figurines		Massive wall segmening community

Site name	Population estimate	Potential evidence for developments in: Social complexity: *Innovative ideas*	*Authoritative roles and potential hierarchy*	*Craft specialisation*	*Formalised communication*
Wadi Fidan C	480-1120				
Tell Ramad II	950-1770				
Atlit-Yam	1090-2040	Water wells	Items of personal adornment		
Hagoshrim VI	1280-2380				
Tell Labwé	1280-2380		Items of personal adornment; variable mortuary treatment	Plaster; green stone and shell beads	
Tell Teo	1280-2380				
‘Ain Ghazal	3500-5030		Items of personal adornment; variable mortuary treatment	Mother of pearl pendant and button	Game board

Site name	References
Wadi Fidan C	Martin and Edwards 2013; Lovell 2014
Tell Ramad II	Colledge and Conolly 2007; Kuijt 2008b; Weiss and Zohary 2011
Atlit-Yam	Galili *et al.* 2004
Hagoshrim VI	Haber and Dayan 2004
Tell Labwé	Ibañez *et al.* 2012; Khalidi *et al*. 2013
Tell Teo	Bocquentin *et al.* 2011
‘Ain Ghazal	Rollefson *et al.* 1993; Rollefson and Kafafi 1997

Appendix E.5: Population and density estimates for all central and southern Levantine PPN villages

Period	ID	Site name	Site type	Site extent (ha)	Final population estimates			People per dwelling			RADC (residential floor area/person m^2)			SPDC (people/ha)		
					Min	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***
PPNA	1	‘Ain Darat	1	0.08	34	74	**49**	1.2	4.9	**2.4**	1.61	7.56	**3.62**	425	925	**608**
	2	Bir el-Maksur	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	3	Borj Barajne	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	4	Ein Suhun	1	0.30	126	278	**184**	1.2	4.9	**2.4**	1.60	7.65	**3.58**	420	927	**614**
	5	El Aoui Safa	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	6	El Hemmeh	1	0.10	69	101	**81**	1.0	1.5	**1.2**	2.26	3.31	**2.79**	686	1006	**846**
	7	Gesher	1	0.15	63	139	**92**	1.2	4.9	**2.4**	1.60	7.65	**3.59**	420	927	**613**
	8	Gilgal III	1	0.10	42	93	**61**	1.2	4.9	**2.4**	1.60	7.65	**3.59**	420	930	**613**
	9	Gilgal IV	1	0.10	42	93	**61**	1.2	4.9	**2.4**	1.60	7.65	**3.59**	420	930	**613**
	10	Hatoula	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	11	Nahal Oren	1	0.05	24	43	**32**	2.0	3.5	**2.8**	2.63	4.65	**3.64**	490	860	**675**
	12	Zahrat Adh-Dhra' 2	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	13	Dhra'	2	0.45	133	298	**191**	2.8	8.0	**4.7**	2.17	5.61	**3.65**	296	662	**424**
	14	Gilgal I	2	0.40	157	287	**211**	2.3	4.7	**3.5**	2.31	4.23	**3.27**	392	717	**555**
	15	Huzuq Musa	2	1.00	295	664	**425**	2.8	8.0	**4.7**	2.17	5.62	**3.64**	295	664	**425**
	16	Jericho	2	2.50	737	1651	**1062**	2.8	8.0	**4.7**	2.18	5.62	**3.65**	295	660	**425**
	17	Netiv Hagdud	2	0.75	215	268	**241**	4.2	5.3	**4.8**	4.02	5.03	**4.53**	286	357	**322**
	18	Tell Aswad IA	2	1.00	295	664	**425**	2.8	8.0	**4.7**	2.17	5.62	**3.64**	295	664	**425**
EPPNB	19	‘Ain Abu Hudhud	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	20	Ein Suhun	1	0.30	126	278	**184**	1.2	4.9	**2.4**	1.60	7.65	**3.58**	420	927	**614**
	21	El Hemmeh	1	0.10	69	101	**81**	1.0	1.5	**1.2**	2.26	3.31	**2.79**	686	1006	**846**
	22	Motza VI	2	0.50	148	330	**212**	2.8	8.0	**4.7**	2.18	5.60	**3.65**	296	660	**425**
	23	Mujahiya	2	0.50	148	330	**212**	2.8	8.0	**4.7**	2.18	5.60	**3.65**	296	660	**425**
	24	Tell Aswad IB	2	1.00	295	664	**425**	2.8	8.0	**4.7**	2.17	5.62	**3.64**	295	664	**425**
	25	Horvat Galil	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	26	Tell Qarassa	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	27	Mishmar Ha’emeq	-	1.00	317	751	**546**	1.2	8.0	**3.5**	1.51	10.14	**3.41**	317	751	**546**

Period	ID	Site name	Site type	Site extent (ha)	Final population estimates			People per dwelling			RADC (residential floor area/person m^2)			SPDC (people/ha)		
					Min	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***
MPPNB	28	Adh-Dhaman I	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	29	‘Ain Abu Nekheileh	1	0.12	86	148	**111**	1.7	2.9	**2.3**	2.61	4.50	**3.56**	713	1231	**972**
	30	Beidha (A2)	1	0.20	79	116	**97**	1.7	2.5	**2.1**	2.57	3.76	**3.17**	395	578	**487**
	31	Jebel Arqa	1	0.20	84	185	**123**	1.2	4.9	**2.4**	1.61	7.65	**3.58**	420	925	**615**
	32	Jebel Rabigh	1	0.06	26	56	**37**	1.2	4.9	**2.4**	1.59	7.41	**3.57**	433	933	**617**
	33	Jebel Ragref	1	0.15	63	139	**92**	1.2	4.9	**2.4**	1.60	7.65	**3.59**	420	927	**613**
	34	Jebel Salaqa	1	0.10	42	93	**61**	1.2	4.9	**2.4**	1.60	7.65	**3.59**	420	930	**613**
	35	Shkārat Msaied	1	0.20	80	149	**109**	2.6	4.9	**3.8**	2.51	4.65	**3.58**	402	745	**574**
	36	Tell Eli IV	2	2.00	590	1321	**849**	2.8	8.0	**4.7**	2.18	5.62	**3.65**	295	661	**425**
	37	Abu Gosh	3	0.25	87	148	**114**	3.1	6.4	**4.5**	1.91	4.82	**3.08**	348	592	**456**
	38	Wadi Hamarash I	3	0.50	147	223	**185**	2.9	4.5	**3.7**	2.55	3.86	**3.21**	294	445	**370**
	39	‘Ail IV	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	40	'Ain Ghazal	4	4.00	1459	2717	**2096**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	41	Beisamoun	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	42	Ghwair I	4	1.325	399	612	**506**	3.8	5.8	**4.8**	2.62	4.02	**3.32**	301	462	**382**
	43	Horvat Galil	4	2.50	912	1698	**1310**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	44	Jericho	4	4.00	1459	2717	**2096**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	45	Khirbet Hammam	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	46	Motza V	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	47	Tell Abu es-Sawwan	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	48	Tell Aswad II	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	49	Tell Ghoraifé I	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	50	Wadi Shu'eib	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	51	Yiftah'el IV	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	52	Mishmar Ha’emeq	-	0.50	159	374	**272**	1.2	8.0	**3.5**	1.51	10.10	**3.42**	318	748	**544**
	53	Munhata IV-VI	-	0.20	63	152	**110**	1.2	8.0	**3.5**	1.49	10.20	**3.38**	315	760	**550**
	54	Nahal Betzet I	-	0.50	159	374	**272**	1.2	8.0	**3.5**	1.51	10.10	**3.42**	318	748	**544**
	55	Tel Roim West V	-	0.50	159	374	**272**	1.2	8.0	**3.5**	1.51	10.10	**3.42**	318	748	**544**

Period	ID	Site name	Site type	Site extent (ha)	Final population estimates			People per dwelling			RADC (residential floor area/person m^2)			SPDC (people/ha)		
					Min	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***
LPPNB	56	Beidha (C2)	3	0.30	141	216	**178**	3.9	6.4	**5.2**	2.33	3.58	**2.96**	469	719	**594**
	57	‘Ail IV	4	2.00	729	1358	**1048**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	58	Ba'ja	4	1.35	584	610	**603**	3.4	3.5	**3.5**	4.04	4.22	**4.13**	649	678	**664**
	59	El Hemmeh	4	1.00	532	795	**664**	2.2	3.2	**2.7**	2.68	4.01	**3.35**	532	795	**664**
	60	Er-Rahib	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	61	Jericho	4	4.00	1459	2717	**2096**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	62	Motza Tahtit	4	2.00	729	1358	**1048**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	63	Qminas	4	1.50	547	1019	**786**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	64	Tell Aray	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	65	Tell el-Ghafar I	4	1.50	547	1019	**786**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	66	Tell Eli III	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	67	Tell Ghoraifé II	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	68	Tell Labwé	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	69	Tell Rakan I	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	70	Tell Ramad I	4	1.50	547	1019	**786**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	71	Tell Ras Shamra V C	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	72	Tel Tif'dan	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	73	Wadi Badda	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	74	Yiftah'el III	4	1.50	547	1019	**786**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	75	'Ain Ghazal	5	10.00	4379	6283	**5206**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	76	‘Ain Jamam	5	7.00	3066	4397	**3644**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	77	Al-Baseet	5	7.50	3285	4712	**3904**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	78	Basta	5	13.00	5693	7854	**6773**	4.8	6.6	**5.7**	2.93	4.04	**3.49**	438	604	**521**
	79	Beisamoun	5	13.50	5912	8480	**7028**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	80	Es-Sifiya	5	8.00	3504	5026	**4165**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	81	Kharaysin	5	10.00	4379	6283	**5206**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	82	Khirbet Hammam	5	7.00	3066	4397	**3644**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	83	Tell Abu es-Sawwan	5	10.50	4598	6598	**5466**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	84	Tell 'Ain el-Kerkh/II	5	16.00	7007	10052	**8329**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	85	Wadi Shu'eib	5	8.00	3504	5026	**4165**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	86	Aviel	-	3.00	952	2249	**1635**	1.2	8.0	**3.5**	1.51	10.13	**3.41**	317	750	**545**
	87	Es-Sayyeh	-	3.50	1111	2621	**1906**	1.2	8.0	**3.5**	1.51	10.12	**3.42**	317	749	**545**

Period	ID	Site name	Site type	Site extent (ha)	Final population estimates			People per dwelling			RADC (residential floor area/person m^2)			SPDC (people/ha)		
					Min	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***	*Min*	*Max*	***Mean***
PPNC	88	Atlit-Yam	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	89	El Hemmeh	4	1.00	532	795	**664**	2.2	3.2	**2.7**	2.68	4.01	**3.35**	532	795	**664**
	90	Es-Sifiya	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	91	Hagoshrim VI	4	3.50	1276	2377	**1833**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	92	Tell Abu es-Sawwan	4	5.00	1823	3396	**2619**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	93	Tell 'Ain el-Kerkh/II	4	6.00	2188	4075	**3143**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	94	Tell Eli III	4	3.50	1276	2377	**1833**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	95	Tell Labwé	4	3.50	1276	2377	**1833**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	96	Tell Ramad II	4	2.60	948	1766	**1362**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	97	Tell Ras Shamra V B	4	3.00	1094	2037	**1571**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	98	Tell Teo	4	3.50	1276	2377	**1833**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	99	Tel Roim West IV	4	1.00	365	679	**523**	2.2	5.6	**3.8**	1.78	5.84	**3.29**	365	679	**523**
	100	Wadi Shu'eib	4	6.00	2188	4075	**3143**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	101	Yiftah'el III (?)	4	1.50	547	1019	**786**	2.2	5.6	**3.8**	1.78	5.85	**3.29**	365	679	**524**
	102	'Ain Ghazal	5	8.00	3504	5026	**4165**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	103	Basta (?)	5	7.00	3066	4397	**3644**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	104	Beisamoun	5	7.00	3066	4397	**3644**	4.7	8.4	**6.5**	-	-	**3.40**	438	628	**521**
	105	Es-Sayyeh	-	2.00	635	1498	**1089**	1.2	8.0	**3.5**	1.51	10.12	**3.42**	318	749	**545**
	106	Wadi Fidan C	-	1.50	476	1123	**817**	1.2	8.0	**3.5**	1.51	10.13	**3.42**	317	749	**545**