Title: Expanding on incremental dentin methodology to investigate childhood and infant feeding practices on Taumako (southeast Solomon Islands)

Authors: Chris Stantis[a], Hallie R. Buckley[b], Amy Commendador[c, d], John Dudgeon[e]

Abstract: Though many ethnohistoric sources in the tropical Pacific recount chiefly feasting events, few describe childhood feeding practices despite the impact childhood under-nutrition may have had on morbidity and early mortality. Bioarchaeological investigation of the Namu burial ground (circa 750–300 BP) on the island of Taumako (southeast Solomon Islands) provides a direct means of understanding prehistoric life on a Polynesian Outlier in the south western Pacific. We investigate infant and childhood (0—10 years) feeding behavior in prehistoric Taumako by creating $\delta^{13}C_{collagen}$, $\delta^{15}N_{collagen}$, and $\delta^{13}C_{carbonate}$ profiles from 20 individuals using horizontal dentin sections of permanent first molars. The high-resolution data created using novel sample preparation offers insight into childhood diet in the absence of documentary evidence, incrementally sampling $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ but also expanding on the method to provide carbonate data from the same sequential dentin samples.

The individuals who died in adolescence have significantly lower $\delta^{15}N_{collagen}$ values in early life than those who died in adulthood, which may suggest a link between diet, nutritional health, and morbidity. There were no significant differences in isotope values between social status groups, suggesting shared childhood experiences regarding types of foods consumed. Longitudinal assessment of $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ shows a strong relationship between the two values, likely a result of the typical tropical Pacific diet consisting largely of high protein marine foods that overshadows low protein terrestrial foods. This highlights the utility of $\delta^{13}C_{carbonate}$ in order to more effectively investigate consumption of low protein foodtypes in this region.

Keywords: carbon; nitrogen; tropical Pacific; Polynesia

Highlights:

- Collagen and carbonate isotope values analyzed on the same transverse tooth sections
- Dietary values showed no differences between wealth groups
- Collagen isotopes difficult to use in this region, as higher protein foods overshadow key cultural foods (root vegetables)

INTRODUCTION

Status-based differences in access to food resources is a phenomenon found throughout human history (Danforth 1999; Darmon and Drewnowski 2008; Twiss 2012), and Oceania was not an exception (Bell 1931; Firth 1936; Firth 1939; Oliver 1989). Though there is a wealth of ethnographic resources regarding the proto-historic and early historic periods in the tropical Pacific (e.g., Beaglehole, 1967, Mariner and Martin, 1827, Ella, 1899, Thomson, 1902) , these tend to focus on the lives of chiefs and other men rather than the daily lives of "others": women, children, and the lower class. In addition, these ethnohistoric sources focused on feasting rather than the daily food access and redistribution among most of the population.

Stable isotope analyses of diet have served as a means of reconstructing past food pathways in the Pacific and elucidating differential access to food between social groups, sexes, and age groups (Commendador et al. 2019; Kinaston et al. 2013a; Stantis et al. 2016a; Stantis et al. 2015). Stepwise nitrogen enrichment in infants being breastfed has been observed in living populations (de Luca et al. 2012; Fuller et al. 2006), with Katzenberg et al. (1993) first noting changes in nitrogen stable isotope values in infants relative to the adult population in an archaeological assemblage.

However, the traditional cross-sectional approach of analyzing the bulk bone collagen from a burial assemblage can suffer from problems of representation when investigating childhood diet (Kendall 2016; Reynard and Tuross 2015). Complications relating to the "Osteological Paradox" should be considered when investigating childhood and infant dietary practices using bulk bone data from subadults in an assemblage: those individuals who died as subadults are non-survivors and might therefore not representative of the *living* population of children from that time period (Lewis 2007; Wood et al. 1992). A different weaning practice may have even been the cause of death for some (Kramer and Kakuma 2004) and so those individuals who survived to adulthood may have lived arguably more "normal" lives within the socio-cultural constructs of their community than those who died as subadults. The Osteological Paradox is a known 'cautionary tale' for bioarchaeologists, and data from bone is still the most popular means of reconstructing population-averaged weaning times with Bayesian modelling strengthening this methodological approach in recent studies (Smith et al. 2017; Stantis et al. 2020; Tsutaya 2017; Tsutaya and Yoneda 2013).

A potential improvement to stable isotope dietary reconstruction is taking a longitudinal approach by analyzing incremental sections of dentin, which allows the explorations of changes in diet while the tooth is forming (Beaumont et al. 2013; Beaumont et al. 2014; Beaumont and Montgomery 2016; Beaumont et al. 2015; Lahtinen 2017; Sandberg et al. 2014). As dentin forms from crown to apex at a highly controlled rate, sections of dentin analyzed along the transverse plane will obtain data with a high temporal resolution (Beaumont and Montgomery 2015). Layers of dentin are mineralized within three to four days (Fuller et al. 2003; Hedges et al. 2007) and, though dentin growth rates vary across the length of the tooth, small (~1-2mm) sections of dentin will capture periods of months rather than the averaged diet over spans of years obtained through bulk collagen analyses (Geyh 2001; Hedges et al. 2007; Szulc et al. 2000). Though skeletal evidence of these adults' childhood disease experiences may have been erased over time due to constant bone formation and resorption (Lewis 2007), the dietary experiences of these individuals is stored in tooth dentin, which largely does not remodel once formed (Goldberg et al. 2011).

This approach to understanding breastfeeding and weaning is not without its own weaknesses. For example, the identical appositional rate of dentin layers is assumed but has not been fully demonstrated (Beaumont et al. 2015). With the dentin depositing in layers of convex curvature (Czermak et al. early view; Eerkens et al. 2011), transverse slices cutting through multiple layers from crown to root might actually represent different spaces of time, making the inference that each section represents an equal amount of growth untrue. Despite these limitations, with high resolution data from permanent tooth dentin, it is possible to assess infant and childhood feeding practices in those individuals who survived childhood to adults by specifically targeting teeth that form during and shortly after birth, a particularly vulnerable period to extrinsic stressors in a person's life (Lewis 2007).

While ethnographic resources inform on some key information about life in this region, stable isotope analyses can provide more direct information on differences in diet and inferences about nutrition and health in these people. Socially-mediated access to certain food groups based on social status, sex, and age have been identified using cross-sectional stable isotopes analysis in Oceania to understand processes and effects of the social constructions that shaped life in the past (Fenner et al. 2015; Kinaston et al. 2014a; Kinaston et al. 2013a; Kinaston et al. 2013b; Stantis et al. 2016a; Stantis et al. 2015; Stantis et al. 2016b; Valentin et al. 2006; Valentin et al. 2011). Using longitudinal methods, it is therefore possible to address questions such as: how were people affected by social differences over the course of their life? And were social differences apparent in childhood?

This paper aims to investigate the relative proportions of plants and animals of terrestrial and marine origin consumed during childhood on the tropical Pacific island of Taumako, and to compare potential social groups using osteological assessment of sex and grave goods as proxies for social status. This study would then add to the previous investigations of past life in Taumako, but with some degree of sensitivity to potential life stage changes. We predict that dietary differences between the sexes and perceived wealth groups as observed in the adult life (Kinaston and Buckley 2017; Kinaston et al. 2013b) will also be observed during childhood for these individuals; males and higher wealth individuals will have had access to more valued food (higher-trophic level marine fish and terrestrial animals such as pig) than women and lower wealth individuals. A secondary aim of this paper is to present an addition to a previously published method of measuring carbon and nitrogen stable isotopes from small sections of dentin collagen (Beaumont et al. 2014). This addition to the Beaumont method maintains the quality parameters and high-resolution collagen data presented there while also measuring the carbon isotope compositions of the inorganic portion of dentin sections, providing another line of dietary evidence.

1.1 Dietary stable isotopes from collagen and carbonate

Investigation of the isotopic composition of archaeologically-derived teeth and bones can provide valuable information about diet and environmental conditions in the past (Lee-Thorp 2008). The analysis of $^{13}C/^{12}C$ ratios (denoted as $\delta^{13}C$) is based off the principle that most of the differences in carbon stable isotope values within food webs arises from the varying $\delta^{13}C$ values of autotrophs due to different photosynthetic pathways (DeNiro and Epstein 1978; Hoefs 2009; Lee-Thorp et al. 1989; Sharp 2017; Tieszen 1991). Terrestrial C_3 plants use the Calvin cycle to fixate carbon from atmospheric CO_2 and will display a $\delta^{13}C$ range between -33 to -23‰ (Marshall et al. 2007; Sharp 2017). Aquatic photosynthetic organisms generally follow a C_3 photosynthetic pathway, but many types of marine algae and cyanobacteria utilize sources of carbon with higher $\delta^{13}C$ values, such as oceanic bicarbonate, which results in the correspondingly higher $\delta^{13}C$ values compared to terrestrial C_3 plants, often between -22 and -17‰ (Fry et al. 1982; Keegan and DeNiro 1988; Schoeninger et al. 1983). Freshwater autotrophs derive their carbon from a variety of sources including atmospheric CO_2, dissolved CO_2, soil bicarbonate, and carbon from organic detritus (Zohary et al. 1994). As a result freshwater fish bones have yielded more variable $\delta^{13}C$ values than marine fish, ranging between -13 to -25‰ (Katzenberg and Weber 1999). Plants that use the C_4 (Hatch-Slack) photosynthetic pathway, such as maize, millet, and sorghum display higher $\delta^{13}C$ values compared with terrestrial C_3 plants, typically between -16 to -9‰, and thus largely overlap in values with marine autotrophs (Sharp 2017).

Stable isotope ratios in consumer tissues are related to dietary values with high fidelity, but differences in fractionation factors between tissues must be recognized in order to investigate dietary patterns

(Hobson and Clark 1992; Tieszen et al. 1983). The carbon stable isotope composition of structural carbonate ($-CO_3$) from bone or tooth hydroxyapatite reflects the isotopic composition of the whole diet (carbohydrates, lipids, and protein) (Balasse et al. 2003; Passey et al. 2005). In contrast, $\delta^{13}C_{collagen}$ largely tracks the protein portion of an individual's diet due to the differences in the metabolic processes involved in creating hydroxyapatite and collagen (Ambrose and Norr 1993; Jim et al. 2004; Lee-Thorp et al. 1989; Tieszen and Fagre 1993). The carbonate-collagen offset ($\Delta^{13}C_{carbonate-collagen}$) can be examined to compare the whole diet to the protein portion: controlled diet studies show evidence that if the offset is greater than 4.5‰ the protein portion is dominated by C_3 terrestrial foods with relatively more C_4/marine whole diet sources while an offset less than 4.5‰ suggests a diet of marine protein sources with terrestrial C_3 whole diet (Ambrose and Norr 1993; Jim et al. 2004). This offset has been examined in prehistoric Rapa Nui (Commendador et al. 2019) to confirm a predominantly terrestrial sourced diet.

The nitrogen stable isotope values ($\delta^{15}N$) in collagen are largely reflective of the protein portion of diet as well but are also indicative of the individual's place in the food web or trophic level. There is a roughly 3—5 ‰ stepwise enrichment between predators and prey (Bocherens and Drucker 2003; Minagawa and Wada 1984; Perkins et al. 2014). Marine food webs are longer and so tend to have higher trophic levels. Used in conjunction with $\delta^{13}C$ values, $\delta^{15}N$ values of collagen can be used to assess an organism's reliance on marine and terrestrial resources. There is also a stepwise enrichment of ^{13}C between trophic levels but the enrichment is often too small (~1‰) to be easily observed except in controlled studies (Bocherens and Drucker 2003; DeNiro and Epstein 1978). With all three isotopic data collected here ($\delta^{13}C_{carbonate}$, $\delta^{13}C_{collagen}$, and $\delta^{15}N$), multivariate statistics can be used to visualize different protein and energy sources (Froehle et al. 2010; Froehle et al. 2012; Kellner and Schoeninger 2007).

There are interpretations of carbon and nitrogen stable isotope ratios beyond traditional dietary studies. The same stepwise enrichment in nitrogen that allows the observation of predator-prey relationships also enables researchers to examine breastfeeding practices, as an infant breastfeeding will be feeding one trophic level higher than their mother (Fuller et al. 2006). Stable isotope values can be examined to interpret foods used during weaning to supplement breast milk (i.e., complementary foods), or to compare childhood foods with those consumed by adults by comparing tooth and bone collagen samples of adults (Tsutaya 2017; Tsutaya and Yoneda 2015). As bone continues to remodel throughout life (Hedges et al. 2007), carbon and nitrogen stable isotopes from bulk collagen in adult bone will represent the averaged diet from the last few years of life, while the data presented here will provide 'snapshots' of periods of time during early childhood. Comparison of bulk collagen data to incremental dentin is possible in the Namu assemblage due to previous research (Kinaston et al. 2013b). Although stable isotope values from adult female bone collagen are sometimes used as comparative data to establish complete weaning values (Jay 2009; Jay et al. 2008), they are not used here as the general trend of shifting values between sections are of more interpretative value (Beaumont et al. 2015; Kendall 2016).

Beyond diet, extreme undernutrition or taxing the body due to illness or growth may also play a role in changes in stable isotope ratios over time. Studies of modern anorexic patients have shown that changes in nitrogen and carbon isotope ratios, previously interpreted as primarily related to dietary factors, may equally be the result of physiological stress, with nitrogen rising and carbon falling during the extreme chronic undernutrition experienced during anorexia, and nitrogen falling and carbon rising as BMI (body mass index) increases if treatment and aftercare are administered (Baković et al. 2017; Mekota et al. 2006; Neuberger et al. 2013). If $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ display negative covariance (i.e., if $\delta^{15}N_{collagen}$ values rise over time while $\delta^{13}C_{collagen}$ values fall), then extreme physiological stress needs to be considered. Both bone and dentin collagen are subject to non-dietary factors affecting isotope values, but incremental sections of dentin do allow an approach to identifying these factors that is much more immune to environment-related shifts and more tightly controlled by genetics than bone (Beaumont et al. 2018; Cardoso 2007; King et al. 2018).

1.2 Site description

The Namu burial ground on the island of Taumako (Solomon Islands) is one of the few archaeological sites on a Polynesian Outlier, one of eighteen or so islands geographically located in the region of Melanesia but with a Polynesian language and Polynesian cultural traits (Feinberg and Scaglion 2012; Kirch 1984b). On Taumako (**Figure 1**) and the other Polynesian Outliers, it is believed that Polynesian-speaking people from the east integrated with the established local Melanesian populations. The introduction of Polynesian people, language, and material culture to Taumako cannot be pinpointed to a single incident and there is evidence of intermittent contact with both the east and west throughout occupation (Bayard 1976; Davidson 2012; Intoh 1999). Taumako is a small island (16.2 km^2 in area) but, as a high volcanic island with a fringing reef rich in marine resources, the variable terrain lends itself to a variety of ecosystems for food exploitation.

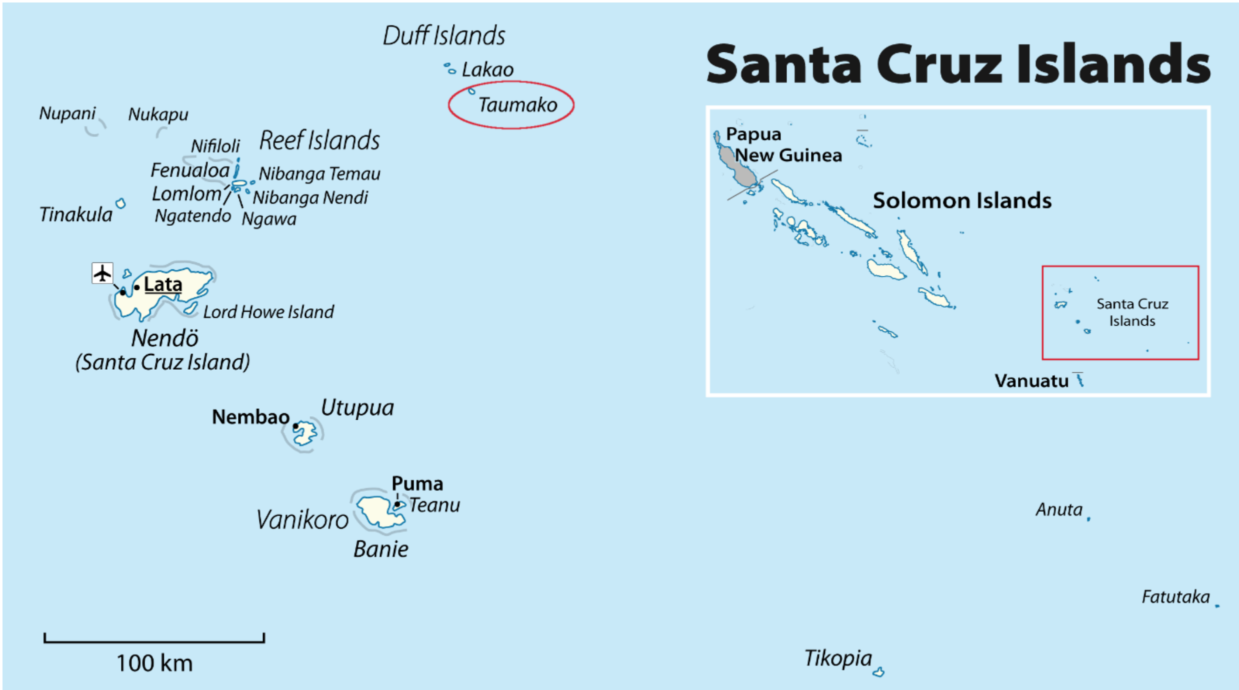

Figure 1. Map of the Duff Islands in the Southeastern Solomon Islands with Taukamo circled in red. Modified from Maximilian Dörrbecker (https://commons.wikimedia.org/w/index.php?curid=14481571)

Namu is a low mound about 70 cm high and 7 or 8 m in diameter (Leach and Davidson 2008). Surface scatter included worked shell fragments, shell money, and human bone fragments. The burials were shallow (maximum depth of excavation was 1 m, and often the density of the burials lessened greatly by 50 cm depth), so shallow that the archaeologists posited that burials were not placed in dug graves so much as placed on the surface and covered with coral gravel. This proposed method of interment is supported by the slight evidence of intercutting with older burials and the burial site name itself. The word *namu* has two meanings in the local language: “mosquito” and “bad smell” (Greenhill and Clark 2011).

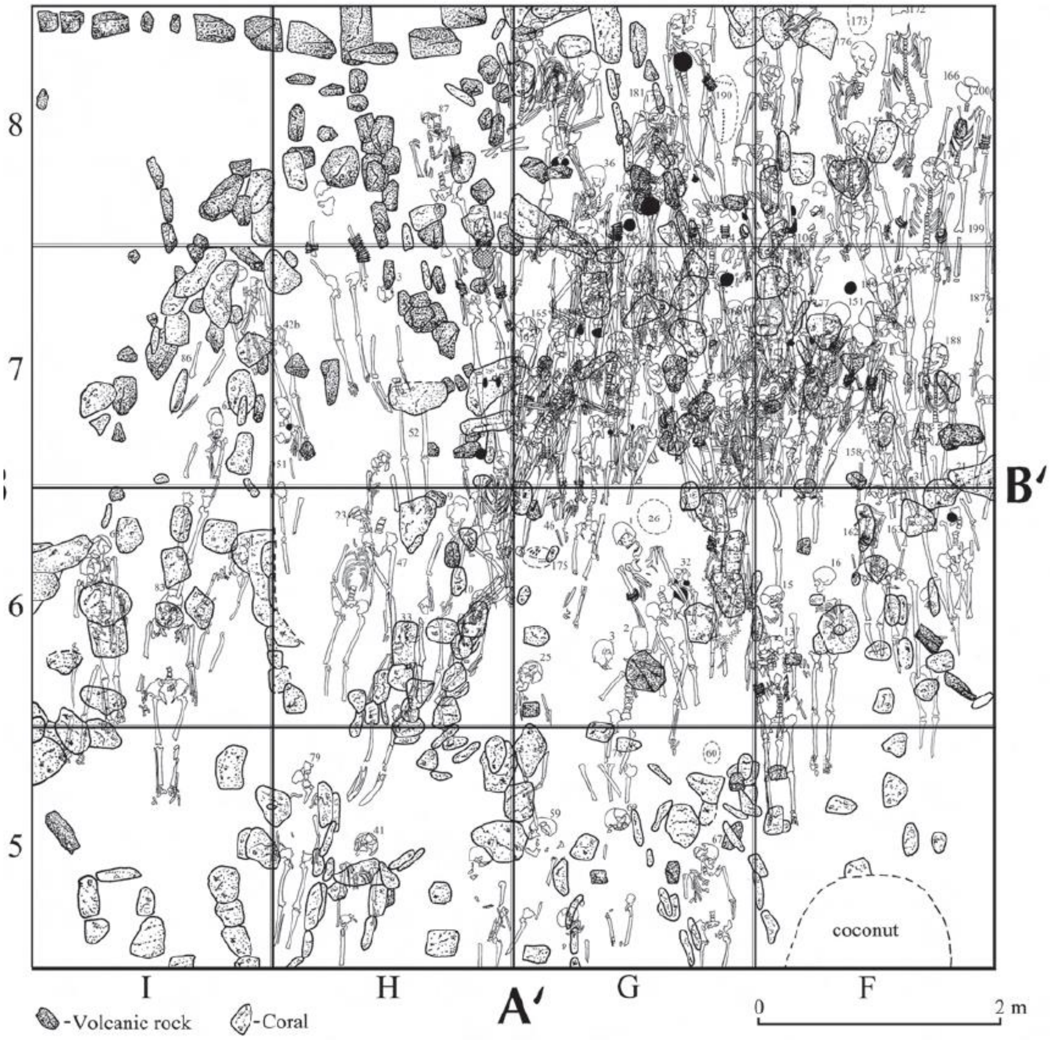

Figure 2. Plan of all burials excavated from Namu. Modified from Leach and Davidson (2008).

The burial site is estimated to have been in use for interring human remains between 750—300 BP (Leach and Davidson 2008), placing the use of the Namu burial ground toward later prehistory on Taumako. Different areas of the burial grounds were believed by the excavating archaeologists to inter kin groups, but the complexity of the site prevented interpretation of the burial configuration (**Figure 2**). Out of approximately 40 m^3 of material excavated, 226 individuals were removed, many of which were nearly complete and relatively undisturbed (Buckley 2016). A few individual bones appear to have been moved, but this was likely due to erosion and/or bioturbation by tree roots, land crabs, or scavenging animals. Many of the 226 individuals excavated from this site are well-preserved providing a large skeletal sample that is rare in the tropics where the heat and humid conditions are unideal for the preservation of bone collagen (Pestle and Colvard 2012).

The rich material culture of grave goods is singular to Namu in the Solomon Islands and includes over 30,000 pieces of shell money as well as ornamental discs, knee and nose ornaments along with amulets and worked flying fox teeth (Leach and Davidson 2008). All shells were species prized as ornamentation rather than consumption, and there were almost no food-related faunal remains in the site. Tubular bone pieces were scattered throughout the burials and may have been parts of red-feather money, the highly valued currency used in the Santa Cruz exchange network (Davenport 1962). Unworked fish and mammal bone were associated with some burial sites and were possibly charms attached to feather money (Koch 1971).

Leach and Davidson created a processual-style enumeration of the grave goods to create a "wealth index" (2008, p. 530). From this wealth index, they found that wealth was distributed unevenly, with 2% of the population buried with 15% of the wealth. Males were accorded more wealth than females (49.7% of the available wealth compared to 27.9%) suggesting higher status. Infants and children were also buried with grave goods, suggesting the Polynesian convention of assigning status at birth (Kirch and Green 2001).

Previous research on this site includes a re-analysis of demography, health and disease of the population (Buckley 2016; Buckley and Tayles 2003a; Buckley and Tayles 2003b) as well as carbon and nitrogen stable isotope analysis of bulk bone collagen from 99 adults, providing insight into diet before death (Kinaston et al. 2013b). Kinaston et al. (2013b) found a relationship between social status (using Leach and Davidson's wealth index) and stable isotope values where wealthy individuals, especially males, were consuming more foods from higher trophic levels. Kinaston and Buckley (2017) also analyzed bulk stable isotopes from teeth of selected individuals to compare adult and child diet in the adult survivors. These studies demonstrated that the skeletal material has not been diagenetically altered to prevent isotope analysis, and that a more detailed investigation of the effects of social status is warranted.

1.3 An Oceanic menu

Diet in Taumako, like most Pacifica diets, centered on C_3 root vegetables such as taro (*Colocasia esculenta*), sago (*Metroxylon sagu*) and yams (*Dioscorea* spp.) along with tree crops such as breadfruit (*Artocarpus altilis*) and bananas (*Musa* spp.) (Kirch 1984a; Kirch 1997). There were very few edible C_4 plants available during the prehistoric period in the tropical Pacific islands. The only cultivated terrestrial C_4 plant consumed in Taumako would have been sugarcane (*Saccharum officinarum*) which forms a small part of horticultural pursuits recorded ethnohistorically (Davenport 1968). Terrestrial native plants were rarely part of the Polynesian horticultural system but can be gathered in times of food scarcity, such as after extensive cyclone damage to gardens (Kirch and Hunt 1997). More commonly eaten native plants are seaweeds and seagrasses, which are gathered today by women and children when foraging for shellfish and other inshore organisms in the lagoons and reefs (Whistler 2007). The accompaniment to staple root vegetables can consist of some sort of meat, most often seafood from the open ocean, reef, or lagoon (Barrau 1961; Pollock 1992) though pigs (*Sus scrofa*), chickens (*Gallus gallus*) and dogs (*Canis lupus familiaris*) have been found in the archaeological record and/or noted during initial European contact (Leach and Davidson 2008; Quirós and Markham 1904).

1. MATERIAL AND METHODS

Twenty permanent mandibular or maxillary first molars with completely formed root apices were selected for this study. Only those teeth which displayed limited attrition, rated four or less on the Smith system (Smith 1984), were included. Additionally, teeth could only have carious lesions penetrating the enamel and not the underlying dentin, and no damage to the roots (ante- or post-mortem) to be valid for selection. To investigate potential differences between social groups, nine individuals were selected with no grave goods (4 male, 5 female) and eleven from the highest echelons of purported "wealth" (3 male, 6 female and 2 indeterminate), as described by Leach and Davidson (2008). The wealthiest individuals were buried with grave goods such as beaded ornamentations: necklaces, anklets or knee decorations. These ornamentations were personalized with worked shells (*Tridacna*, *Nautilus*, *Polynices*), flying fox and shark teeth, and ivory reels.

In total, eleven individuals were female, seven males, and two were of indeterminate sex. The two individuals of indeterminate sex were adolescents of estimated median ages of 12 and 15.5. The other 18 individuals are adults of estimated age twenty or older. There was a range of visible pathologies observed in this selection of individuals, including two individuals with possible treponemal disease (Buckley and Tayles 2003b)(Table 1).

The permanent first molar, both mandibular and maxillary, typically begins formation just before birth and completes formation about 9 or 10 years of age (AlQahtani et al. 2010). Thus, conducting stable isotope analyses on the dentin within the crown will cover the period of breastfeeding and weaning while the root dentin captures later childhood diet (Table 2).

All samples were processed and analyzed at the Center for Archaeology, Materials and Applied Spectroscopy (CAMAS) at Idaho State University. Surface debris was removed using a slow-speed burr, and then the teeth were sliced lengthwise using a diamond trim saw. The enamel was separated from the dentin using a combination of a burr and saw attachment for a rotary cutter and the surface of the now-exposed pulp chamber was also burred to remove any secondary or tertiary dentin.

One tooth root half was placed in floral foam and then sawed into 2 mm sections along the transverse plane. If we use Beaumont and Montgomery's method of assigning age to dentin sections, each section would capture roughly 18 months, though we understand that there must be some individual variation in growth, along with the approximately 0.4 mm of dental material lost due to the width of the saw. The pulp chamber and root canals were abraded to remove secondary and tertiary dentin, which, unlike primary dentin, remodels throughout life (Nanci 2013).

These dentin sections were cryomilled after sonication in 18 M-Ohm water and drying in a low temperature (50°) oven. A portion of the powdered sample was set aside for preservation assessment via attenuated total reflection, Fourier transform infrared (FTIR-ATR) spectroscopy. Once washed, cut and ground by cryomill, and prior to any chemical alteration, approximately 2 mg of bone powder was placed on the window of the FTIR. Absorbance spectra was then collected at a resolution of 4 cm-1 and 24 scans. Three spectra were collected from each sample and the values averaged. After each data collection, the sample was mixed and re-centered on the FTIR window to randomize any geometric effects of powder orientation. All spectra were baseline corrected prior to performing peak integration, following Hollund et al. (2013). Values for archaeological samples from Taumako and a larger dataset including additional Pacific samples were then compared to those derived from modern. CO_3 /PO_4 (C/P) ratios and infrared splitting factor (IRSF) for both were then compared to the data produced by Beasley et al. (2014).

After FTIR, samples were recollected to be rinsed in 2% bleach for 72 hr (changing every 24 hr) and then placed in 0.1 M acetic acid for 12 hr. After drying, the powdered samples were weighed out for carbonate analysis on a GasBench II routed onto a ThermoScientific Delta Advantage stable isotope ratio mass spectrometer (Waltham, MA USA; Coleman, 2012).

The other tooth root half was prepared using a modified Longin method (Brown et al. 1988; Longin 1971) and placed in 0.3 M HCl solution to be demineralized. The solution was replaced every 48 hr until the sample was partially demineralized enough to facilitate cutting into 2 mm sections. Once the 2 mm sections were achieved, the samples were placed back on 0.3 M HCl to complete the demineralization process. After rinsing to neutral with deionized water, samples were placed on 0.1 M NaOH for 8 hours to remove soil contaminants. After once again rinsing to neutral, samples were gelatinized at 70°C in a

0.01 M HCl solution. Samples were then frozen and freeze dried for 48 hrs and weighed into tin capsules for analysis on a Thermo Delta V Advantage Isotope Ratio Mass Spectrometer, with a ConFlo IV interface and Costech Elemental Analyzer. Measurement precision is ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. All $\delta^{13}C$ and $\delta^{15}N$ isotope values are reported relative to the Vienna Pee Dee Belemnite (VPDB) (carbon) and atmospheric air (nitrogen) standards.

2. RESULTS

All collagen samples analyzed showed signs of good preservation: C:N within 2.9 and 3.6 (DeNiro 1985), %C wt between 15—47%, and %N wt between 5—17% (Ambrose 1990; Ambrose and Norr 1992). Poor preservation did not preclude any samples from being included in our analyses due to collagen quality parameters. Instead, all poorly preserved samples were realized during the demineralization process, where pseudomorphs degenerated to the point where the tooth roots degraded and dissolved into the solution, completely lost for analysis. Due to this issue, several individuals are only represented by the first few sections representing the crown and beginning of the root; the worst preserved in this collection was Burial 32, where only the first two sections survived the demineralizing and cutting process.

Regarding the dentin sections analyzed for $\delta^{13}C_{carbonate}$, FTIR analysis showed generally good preservation in the mineral portion of the dentin following guidelines by France et al. (2020): C/P ratios were between 0.05—0.3 and IRSF were between 3.1—4.3 with the exception of one sample (Burial 34 Section 6) which had a slightly lower IRSF value of 2.72. Higher IRSF values are of greater concern as they suggest mineral recrystallization (France et al. 2020), and so this lower value is noted but the $\delta^{13}C$ value is included in data analysis. Ultimately, preservation was not an issue for the inorganic portion of dentin in the same manner as the dentin collagen. Instead, the issue preventing output data was sample size, with several samples too small to yield $\delta^{13}C_{carbonate}$ values. This tended to pose a problem in the first few sections in the crown, as the horns of the crowns yielded sample sizes too small to analyze when cut in 2mm sections.

Despite these issues, we obtained 264 points of stable isotope data from the twenty individuals for the suite of three stable isotope analyses from the dentin sections. All stable isotope data are presented in Supplementary Table 1. The summary of stable isotope data is presented in Table 3.

3.1 δ^{13}C$_{collagen}$ and δ^{15}N$_{collagen}$

There are several ways to present longitudinal δ^{13}C$_{collagen}$ and δ^{15}N$_{collagen}$ data. First, the nitrogen and carbon stable isotope data can be assessed in bulk to place the general childhood diet within the framework of the available dietary baseline (**Figure 3**). As first molars begin calcification just before birth and end around nine to ten years of age (AlQahtani et al. 2010), the first few sections of a tooth can be expected to record breastfeeding signals. For this examination, we drop the first two 2mm sections beginning at the crown which would capture the first ~36 months of life to prevent the breastfeeding signals from clouding interpretation, understanding that weaning may have been a longer process and later sections might also reflect breast milk consumption (Kendall 2016; Kennedy 2005). There is a moderate positive correlation between δ^{13}C$_{collagen}$ and δ^{15}N$_{collagen}$ values of "post-weaning" tooth sections (Spearman's, $r_s(41) = 0.679$, p <0.001).

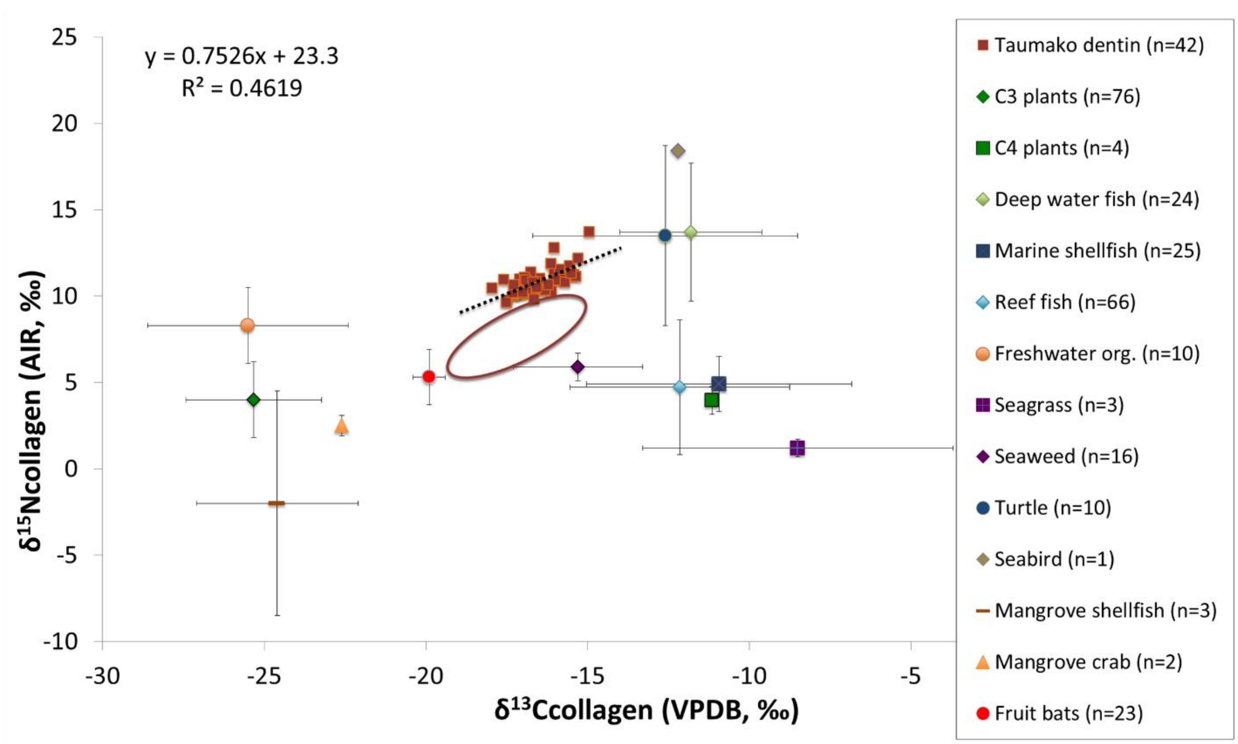

Figure 3. δ^{13}C$_{collagen}$ and δ^{15}N$_{collagen}$ values plotted with fitted regression line (first two tooth sections excluded). Dietary baseline data from previous studies (Kinaston et al., 2014a,b).The enclosed circle indicates the diet of the individuals once corrected for trophic level, -1 for δ^{13}C and -4‰ for δ^{15}N values.

We also plot the averaged $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ from the 'post-weaning' tooth sections to the adulthood diet of the 99 individuals analyzed by Kinaston et al. (2013b) as well as other dietary stable isotope studies from late prehistoric/proto-historic sites in the tropical Pacific (**Figure 4**). The childhood diet observed in dentin overlaps with the adult diet found by Kinaston et al. (2013c) in Taumako, though childhood diet on average shows slightly lower $\delta^{15}N_{collagen}$ values (10.9 ± 0.8‰ compared to 11.5 ± 0.9‰). **Figure 5** plots the $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ across each individual's life course. The significant positive covariance can be visually confirmed in this figure, as the two collagen values tend to move together.

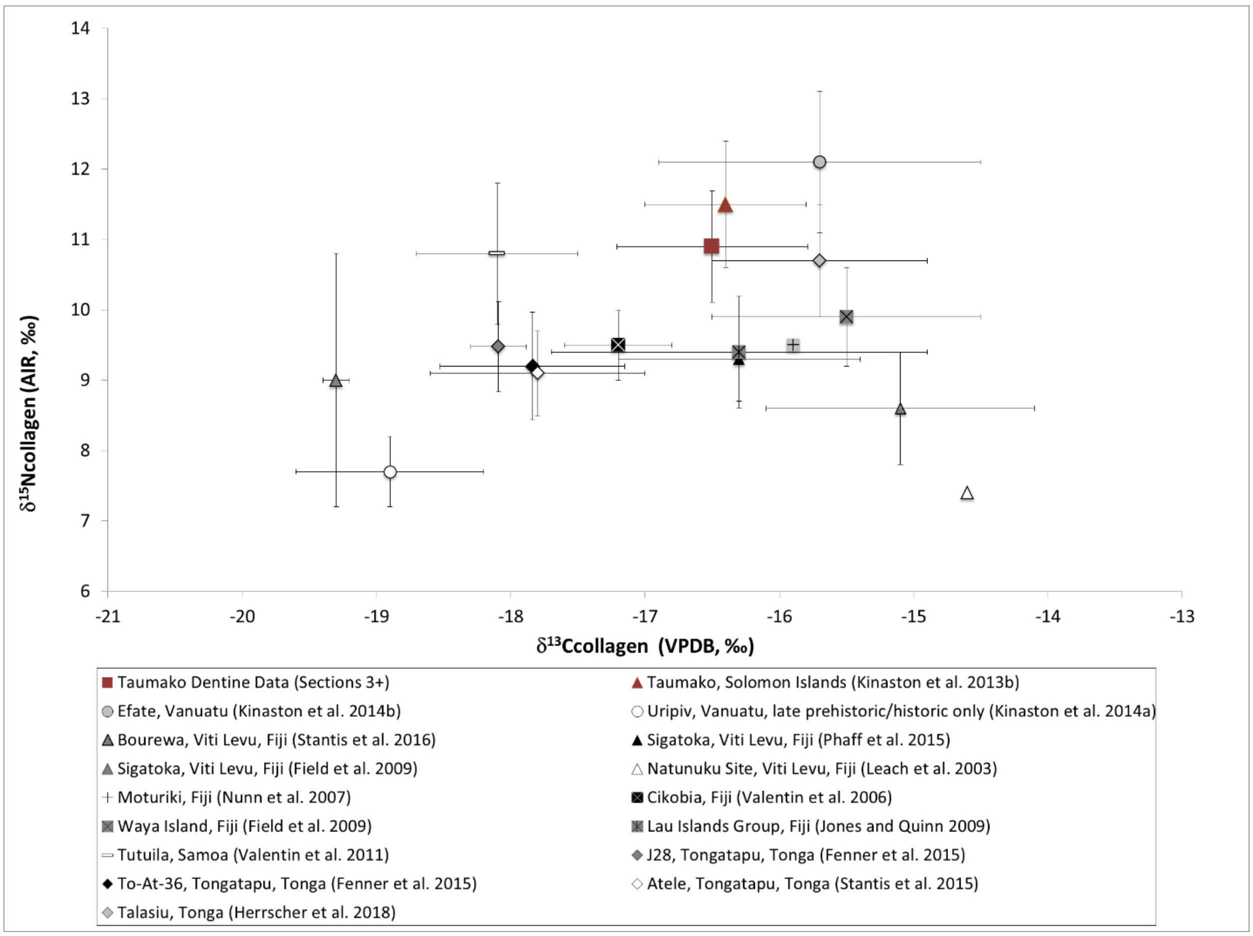

Figure 4. $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ mean ±SD for the Taumako dentin sections (excluding the first two sections of the crown) compared to other tropical Pacific sites in the geographic regions of West Polynesia and Melanesia (Fenner et al. 2015; Field et al. 2009; Herrscher et al. 2018; Jones and Quinn 2009; Kinaston et al. 2014a; Kinaston et al. 2014b; Kinaston et al. 2013b; Leach et al. 2003; Leach 2003; Nunn et al. 2007; Phaff et al. 2015; Stantis et al. 2016a; Stantis et al. 2015; Valentin et al. 2006; Valentin et al. 2011).

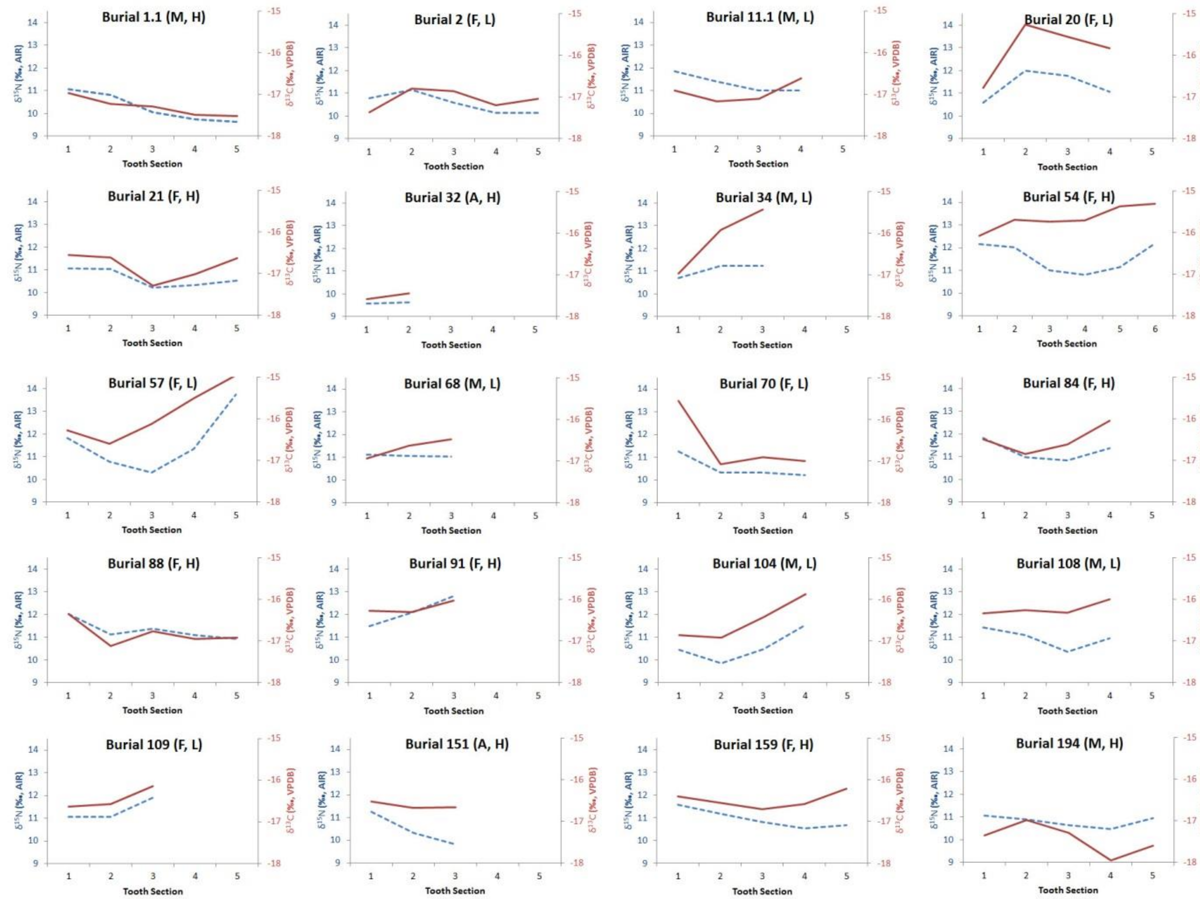

Figure 5. $\delta^{13}C_{collagen}$ (blue, dashed) and $\delta^{15}N_{collagen}$ (red, solid) plotted by tooth section for every individual. Tooth sections numbered sequentially from crown to apex. Variation in data line lengths represent samples with poor preservation of one or more sections of the roots (e.g., Burial 32 having only the first two sections) M = Male, F = Female, A = Adolescent; L = Low Status, H = High Status.

3.1.1 Comparing social status and sex groups

The individual longitudinal data can be pooled into groups by social status and sex. Though the sample size is small on the individual level, main effects for social status and sex can be investigated using one-way ANOVAS with an averaged value per burial across all repeated measures (i.e., aggregated stable isotope values across tooth sections). Two-way ANOVAs would have reduced Type II errors during statistical testing but were inappropriate for the data as there would be a missing subgroup (there are no lower status individuals of indeterminate sex). $\delta^{13}C_{collagen}$ values are normally distributed, and $\delta^{15}N$ values are normally distributed if one outlier (tooth section 5 of burial 57, with a value of 13.7‰) is excluded from testing.

Regarding $\delta^{15}N$, there were no statistically significant differences between social status means (aggregated by tooth section) as determined by a one-way ANOVA ($F(1,18) = 1.034$, $p = 0.323$). There was a significant effect of sex on $\delta^{15}N$ values ($F(2, 17) = 7.093$, $p = 0.006$). Post hoc comparisons using the Tukey test found differences between indeterminates and females ($p = 0.004$) and between indeterminates and males ($p = 0.03$). For $\delta^{13}C_{collagen}$, there were no significant differences between social status group means ($F(1, 18) = 0.992$, $p = 0.332$) or sex ($F(2,17) = 0.2.765$, $p = 0.912$). Visual examination of **Figure 6** reveals that there is rarely more than 1‰ difference in $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ between wealth groups, barring tooth section five which shows high variability in the low-status group. When examining $\delta^{15}N_{collagen}$ grouped by sex, females tend to be 1—2‰ higher than males when comparing each tooth sections' average values, with the adolescents of indeterminate sex falling more towards the males' values.

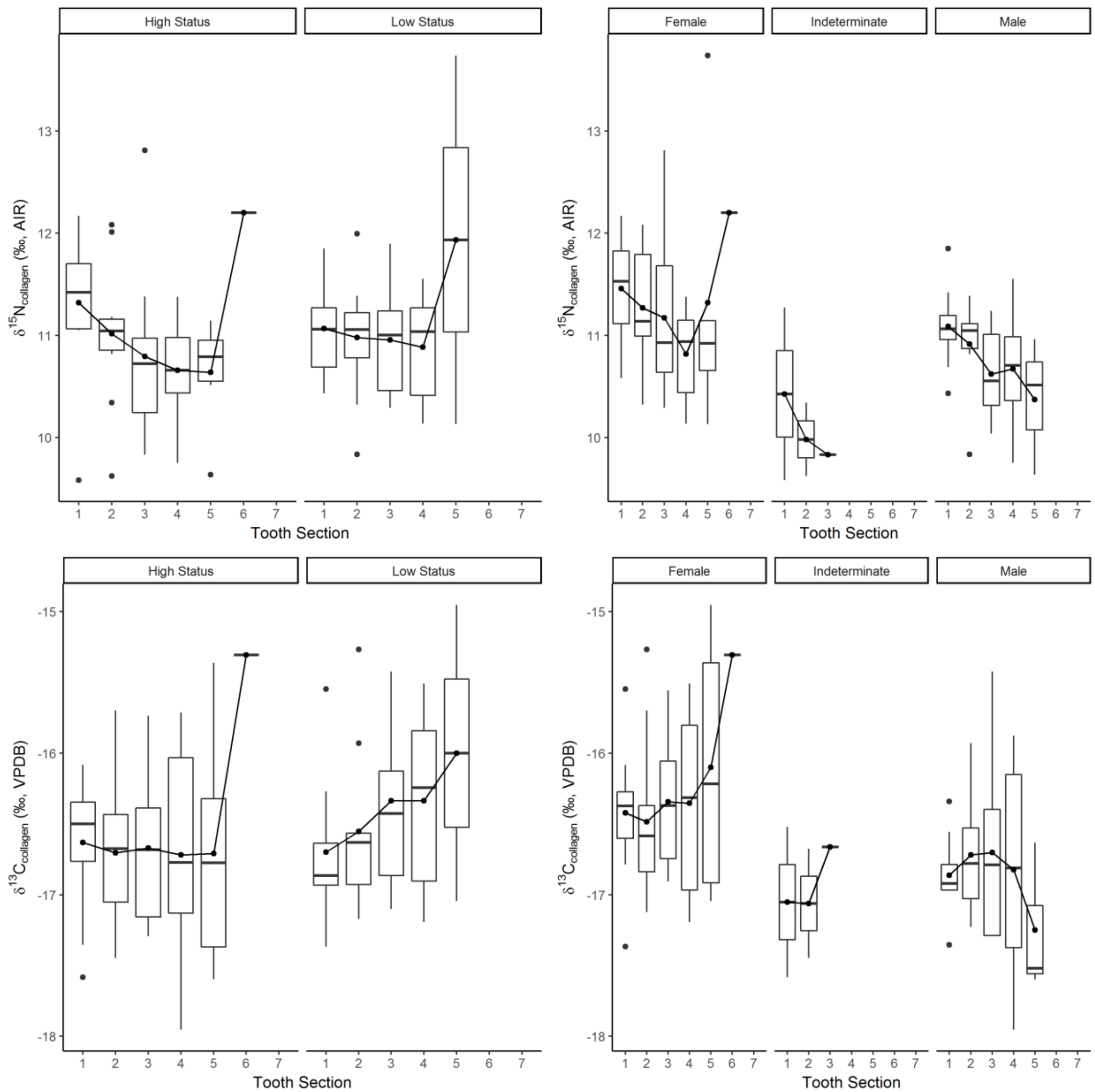

Figure 6. Boxplots of $\delta^{15}N_{collagen}$ and $\delta^{13}C_{collagen}$ values for the social status and sex groups by tooth section. Tooth sections numbered sequentially from crown to apex.

3.2 $\delta^{13}C_{carbonate}$

$\delta^{13}C_{carbonate}$ values were normally distributed, and one-way ANOVAs showed no statistically significant differences in $\delta^{13}C_{carbonate}$ values between social status groups (F(1,18) = 0.001, *p* = 0.981) or sex (F(2,17) = 2.881, *p* = 0.084) (**Figure 7**). The $\delta^{13}C_{carbonate}$ data can be compared to the $\delta^{13}C_{collagen}$ data, although this comparison is made difficult by the differential preservation of the organic and inorganic portions of the dentin in some burials. Of the 82 collagen and 97 carbonate sections acquired, 68 overlap for comparison and $\Delta^{13}C_{carbonate\text{-}collagen}$ calculation. There is a weak but significant negative correlation between $\delta^{13}C_{carbonate}$ and $\delta^{13}C_{collagen}$ values, (Pearson's, $r_s(67) = -3.65$, *p* = 0.002).

When $\Delta^{13}C$ values are plotted for each individual, there appears to be clustering above and below 3‰, where individuals stay within a cluster through the time period captured by these molars (**Figure 8**). There were no significant differences between social status groups regarding $\Delta^{13}C$ values (F(1, 18) = 0.158, *p* = 0.696). Only four $\Delta^{13}C$ values from the indeterminate individuals are available, and so this group is dropped when analyzing sex-based differences among group means; there are significant differences in $\Delta^{13}C$ values between males and females (F(1,16) = 4.534, *p* = 0.049).

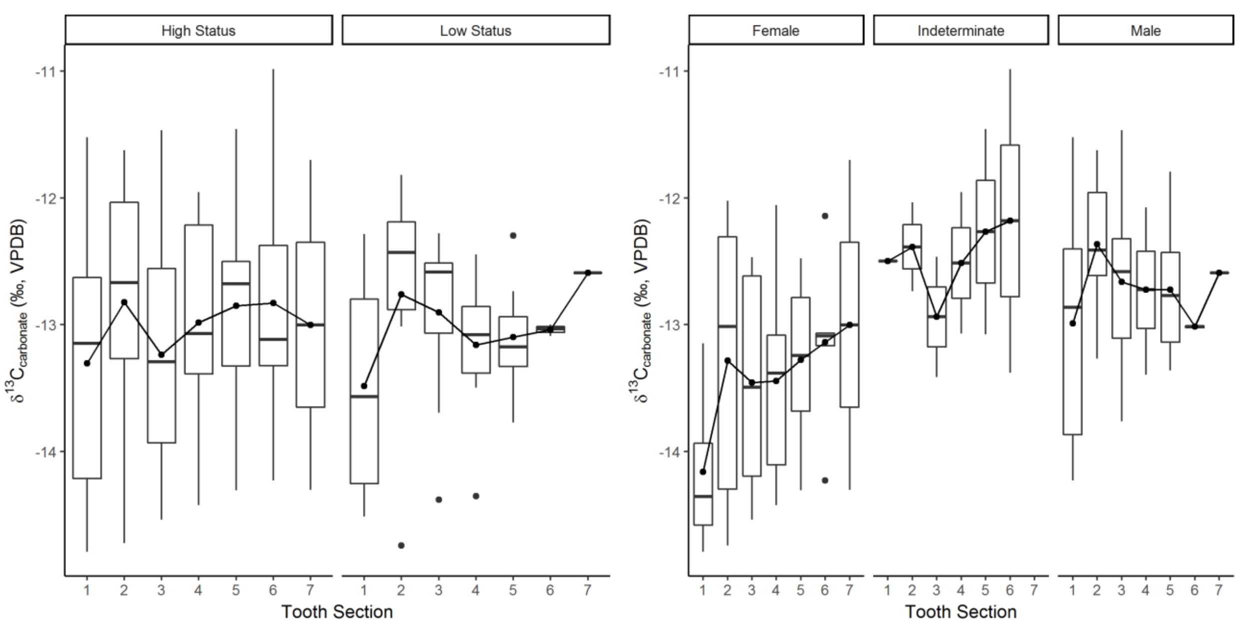

Figure 7. Boxplots of $\delta^{13}C_{carbonate}$ values for the social status and sex groups by tooth section. Tooth sections numbered sequentially from crown to apex.

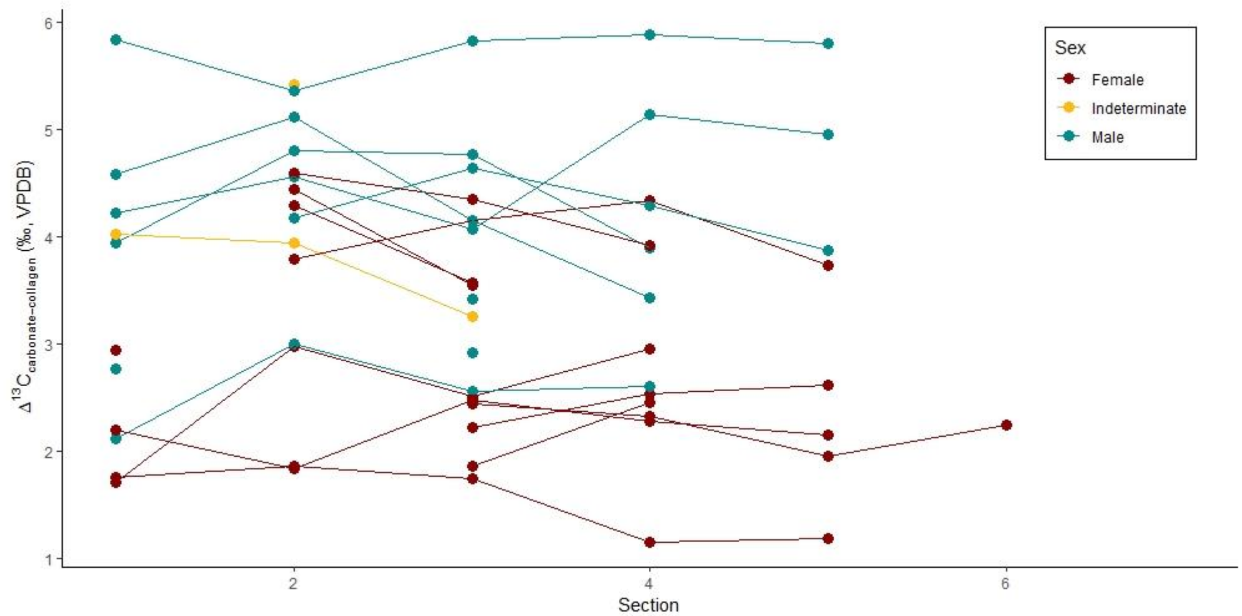

Figure 8. $\Delta^{13}C_{carbonate\text{-}collagen}$ values for each individual plotted by section. Tooth sections numbered sequentially from crown to apex.

2.3 Multivariate Discrimination

Discriminant function analysis suggests a diet consisting of between 65—100% C_3 protein with some sourcing from C_4 terrestrial foods (**Figure 9**). All samples fall within or near both Clusters 1 and 4, apart from one sample (Burial 57, tooth section 5), which displays the highest $\delta^{13}C_{collagen}$ and $\delta^{15}N$ values in the dataset. Cluster 1 represents a 100% C_3 diet and Cluster four represents a 70:30 C_3: C_4 diet with ≥65% protein. The first two sections from teeth are plotted separately from the other sections representing later periods of life, although they overlap. A one-way MANOVA shows no significant differences in F1 and F2 values between earlier (1—2) and later (3+) tooth sections, $F(2, 65) = 0.448$, $p = 0.641$.

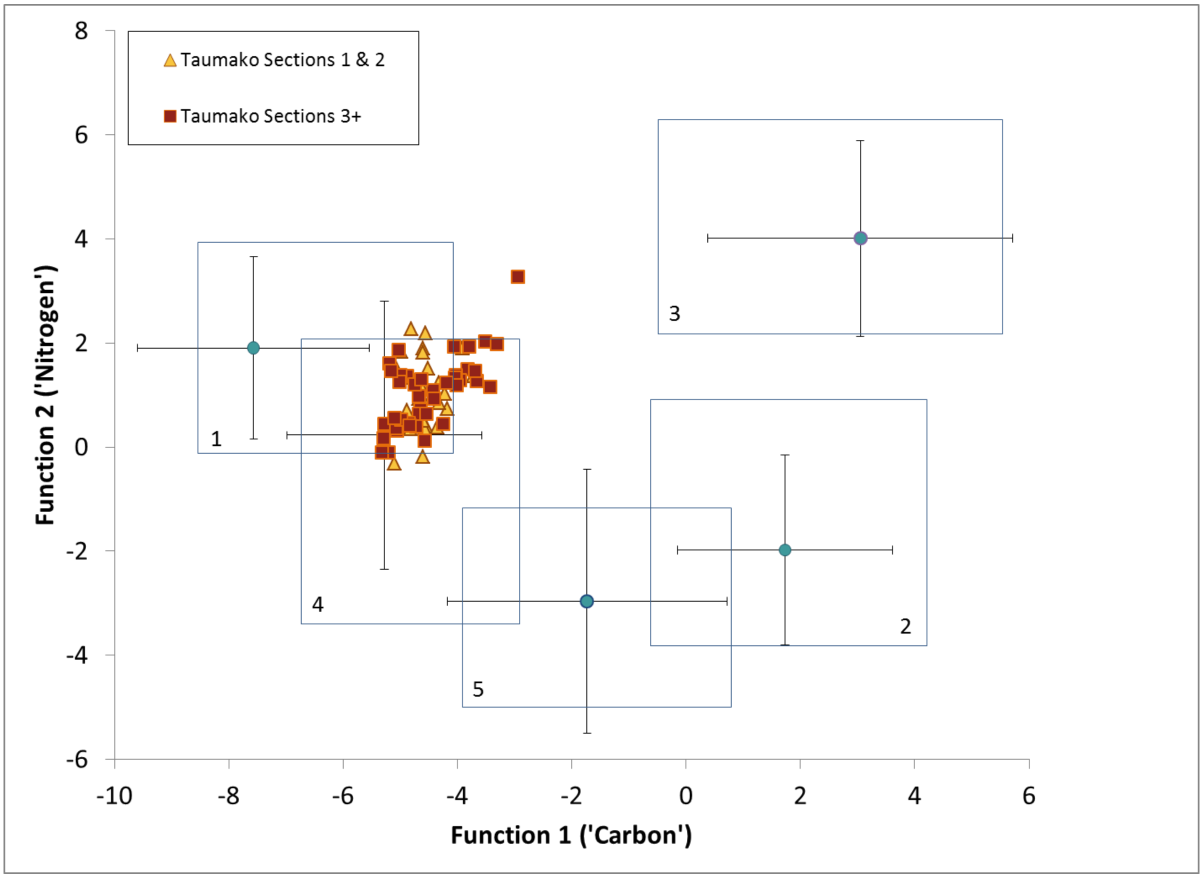

Figure 9. Discriminate function analysis of stable isotope data from Taumako plotted against diet clusters generated by Froehle et al. (2012). Clusters represent the following diets: (1) 100% C3 diet/protein; (2) 30:70 C3:C4 diet, >50% C4 protein; (3) 50:50 C3:C4 diet, marine protein; (4) 70:30 C3:C4 diet, ≥65% C3 protein; (5) 30:70 C3:C4 diet, ≥65% C3 protein.

3. DISCUSSION

The analysis of 2 mm sections generally provided sufficient material for stable isotope analysis; even though bone quality affected information gained for $\delta^{13}C_{collegen}$ and $\delta^{15}N_{collagen}$ for some sections, this was not a result of lack of material but poor collagen preservation, an issue researchers will commonly face in the hot and humid Pacific environment.

Placed against a dietary baseline collected from across the tropical Pacific, the isotopic data collected here conforms to the expectations from past ethnoarchaeological investigations of diet as well as the previous isotopic study. Examining Figure 3, the protein portion of the diet tends towards terrestrial plants (relatively low $\delta^{13}C$ and $\delta^{15}N$ values) and higher trophic order marine foods (relatively high $\delta^{13}C$ and $\delta^{15}N$ values) as evidenced by the moderate positive correlation between $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$. The fruit bat bones are assumed to represent a mammal consuming a 100% C_3 terrestrial diet, and no individuals follow that dietary pattern. Instead, after considering trophic shift, the protein portion of the diet represents marine foods supplemented with terrestrial plant foods and terrestrial animals, though it is understood that low-protein terrestrial plant foods would be overshadowed by the higher protein marine foods in the collagen dietary data.

This comparison across time periods and archipelagoes in the geographic regions of Melanesia and Polynesia is simplistic (and a detailed metadata analysis of the stable isotope data gathered thus far is an avenue for future research), but highlights that the childhood diet observed in dentin overlaps with the adult diet found by Kinaston et al. (2013c) in Taumako, though childhood diet on average shows slightly lower $\delta^{15}N_{collagen}$ values (10.9‰ ± 0.8 compared to 11.5‰ ± 0.9). When these new data are placed in context with previous Pacific studies, the childhood diet involved relatively more marine animal consumption than most other populations. This study's post-breastfeeding data (acknowledging that breastfeeding may have occurred past the age of 18 months and some of these higher-numbered tooth sections may reflect some breastfeeding signal) displays lower nitrogen and carbon isotope values on average than the Taumako adult bone collagen from Kinaston et al. (2013b), but generally clusters with the adult Taumako data in comparison with the other Pacific sites.

This higher reliance on marine foods compared to many other prehistoric Pacific populations is expected given the geography of Taumako. It is a relatively small high volcanic island with rugged terrain that does not lend itself to intense horticultural production, and so the large fringing reef will have been even more important for subsistence.

The positive correlation between $\delta^{13}C_{collagen}$and $\delta^{15}N$ supports the concept of a diet consisting of low trophic level terrestrial foods with higher trophic level marine food endpoints. This positive correlation has been observed in other tropical Pacific collections: the Marianas Archipelago, Tonga, Fiji, and in the adult bone collagen values of the Taumako assemblage (Ambrose et al. 1997; Kinaston et al. 2013b; Stantis et al. 2016a; Stantis et al. 2015; Valentin et al. 2006). The moderate, though significant, positive correlation between carbon and nitrogen stable isotope ratios suggests that the differences in diet between individuals are a result of the different proportions of marine and terrestrial foods eaten. There would be a lack of positive correlation if the population relied mainly on terrestrial and marine foods of the same trophic level or a single protein source (Richards and Hedges 1999). Instead, the dietary trend suggests that the population generally relied on marine animals (relatively high $\delta^{13}C$ and $\delta^{15}N$ values) and terrestrial plants (relatively low $\delta^{13}C$ and $\delta^{15}N$ values). This fits with the estimated diet, where starchy root vegetables such as taro, yams, and fruit trees were central to subsistence along with marine foods from the lagoon and reef. Multivariate modelling, however, predicts a different dietary pattern. The discriminant function scores created by Froehle et al. (2012) suggest that the Taumako population did not rely greatly on marine resources. Instead, the multivariate model predicts a general diet dominated by C_3-derived foods with some C_4 terrestrial input and insignificant marine input. These Taumako values derived from discriminant functions are similar to the prehistoric Rapa Nui humans analyzed by Commendador et al. (2019); the Rapa Nui data also plotted within Clusters 1 and 4 of Froehle et al.'s model. More multivariate modelling in the Pacific environment might elucidate why this model is predicting a dietary pattern different from evidence, especially as this model is not derived from any tropical island groups.

The strength in incremental sections of dentin is not placing the data en masse but looking at the dietary changes across an individual's life course (Figure 5). When plotting $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ by individual, it becomes evident how the $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ values almost always mirror each other, rising and falling in tandem for all individuals. This pattern makes sense within the context of collagen metabolization and the typical Pacific diet of high protein marine foods with high $\delta^{13}C$- and $\delta^{15}N$-values and low protein terrestrial foods with low $\delta^{13}C$- and $\delta^{15}N$-values. Due to preferential routing of dietary protein components to collagen formation isotopic values of collagen tends to reflect the protein portion of the diet (Webb et al. 2017). As such, they are more heavily influenced by the protein-rich food sources. As a person ate relatively less protein-rich marine foods compared to terrestrial foods, their $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ values would decrease in tandem just as their collagen values would increase with the consumption of relatively more protein-rich marine foods at least as observed in bulk collagen data. This pattern is in line with the significant positive correlation we see when we plot the data together and this bias demonstrates how important analyzing $\delta^{13}C_{carbonate}$ is to understand the whole diet. What is not evident in Figure 5 is any negative covariance: the rise of one value combined with the fall of the other. This suggests these individuals did not experience any severe physiological stress.

Negative covariance was not observed in this dataset when each individual's $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ was plotted, with the exception of the small crossing of values in Burial 11.1. This suggests these individuals did not experience any severe physiological stress (Baković et al. 2017; Beaumont et al. 2015; Mekota et al. 2006; Neuberger et al. 2013). As endemic treponemal disease was observed in other individuals in this population (Buckley 2016), a comparative analysis of longitudinal changes in stable isotopes values of those showing skeletal evidence of treponemal disease may help us consider the physiological consequences of disease onset and infection in the past. This would require a larger cohort than the twenty individuals analyzed here.

If we consider breastfeeding and weaning, we would expect a decrease in nitrogen values after the first few tooth sections as these individuals were weaned (Fuller et al. 2006). Although we acknowledged the potentiality that weaning might be affecting nitrogen values after section 2 in individuals that does not seem to be the case. Instead, we largely either observe: 1) higher $\delta^{15}N$ after section 2 compared to the first two sections, which we would not expect if breastfeeding was practiced throughout sections 1 and 2, or 2) declining $\delta^{15}N$ before or after section 2, suggesting weaning around that time. Ten individuals (Burials 1.1, 11.1, 21, 57, 70, 88, 151, and 159) show the expected weaning trajectory in nitrogen along with a tandem decrease in $\delta^{13}C_{collagen}$ values. Another four (Burials 54, 68, 108, and 194) display the decrease in nitrogen stable isotope values though without the accompanying decrease in carbon values. Six burials (burials 2, 20, 32, 34, 91, and 109) show an increase in nitrogen values between tooth sections one and two. Of those individuals, all but Burial 34 are female, and all but Burials 32 and 91 are buried with no grave goods.

These data taken individually suggest there is no obvious weaning pattern, whether as a result of weaning variance culturally, changes over time, or the small sample size obscuring wider patterns. However, when the $\delta^{15}N$ values are grouped by sex or status in Figure 6, we do see a general decrease in mean values over time, suggesting some pattern of weaning even if the pattern is not completely clear. This variance might be reflective of different weaning trajectories depending on individual factors such as maternal/infant health, food availability, the mother's work patterns, and infant agency in the weaning process (Dettwyler 2004; Stuart-Macadam 2017).

Regarding the comparison between sex and wealth groups, there are small differences but overall the values suggest similar diets between social groups as children. These findings contrast with the adult diet observed by Kinaston et al. (2013c), where wealthier individuals and males consumed foods from a higher trophic level, and are in agreement with Kinaston and Buckley (2017) who analyzed bulk samples of dentin and found no childhood dietary differences between the sexes.

Though non-significant, females display higher $\delta^{13}C_{collagen}$ and lower $\delta^{13}C_{carbonate}$ values compared to males. This contrast could occur if females' protein consumption involved relatively more marine foods while their total diet was terrestrial, creating a potential menu of terrestrial staple crops supplemented with fish for women. In contrast, men's diet involved slightly less terrestrial stable crops (hence the higher $\delta^{13}C_{carbonate}$ values) with their protein sources involving more of the socially valued terrestrial animal flesh (e.g., pork). This agrees with Kinaston et al. (2013c), although it must be stressed that these differences in stable isotope values are small, about 1.5‰ between tooth section averages. Nonetheless, the differences highlight how carbonate and collagen stable isotope values can record very different aspects of the same reality.

Of the $\Delta^{13}C$ data available from this study, two clusters appear: individuals with values that stay between 1—3‰throughout the time captured, and individuals with values that are greater than 3‰, ranging 3—6‰. Eight burials are in the 'lower' cluster (Burials 20, 34, 54, 57, 84, 88, 108, and 159) and twelve in the 'upper' cluster (Burials 1.1, 2, 11.1, 21, 32, 68, 70, 91, 104, 109, 151, 194). The wealth groups are relatively evenly distributed among these clusters, but there seems to be more females in the lower cluster (6/8 or 75%) compared to the upper cluster (4/12, 33%). This pattern, along with significant differences in $\Delta^{13}C$ values supports the supposition that males and females had a different dietary pattern throughout their life.

At Taumako, it is interpreted that when infants and children were buried with grave goods it was suggestive of wealth and ascribed status. However, ethnographic sources have found that, in terms of day-to-day practice, Polynesian societies such as Tonga, Fiji, the Cook Islands, and New Zealand treat children as among the lowest rank in societies regardless of familial status (Jones 2009; Ritchie and Ritchie 1979). Ascribed status may not have affected children's access to food during communal meals, although there were still some significant differences between the sexes. There are no modern ethnographies of gendered work on Taumako, but these differences could be the result of girls and women going to the lagoon to gather mollusks and small fish while boys tended the gardens or went fishing with their male relatives; this activity is often considered women's work in Polynesia, and lagoon foods could easily be eaten raw on-site. However, this supposition would not explain why adult women did not display higher nitrogen values in Kinaston et al.'s (2013c) previous work.

A positive correlation has been reported when $\delta^{13}C_{carbonate}$ and $\delta^{13}C_{collagen}$ have been statistically compared in archaeologically-derived samples from North America and South Africa (France and Owsley 2015; Loftus and Sealy 2012); this is the first study to report a negative correlation between the two variables. There is less comparative $\delta^{13}C_{carbonate}$ data in archaeological Pacific studies than for stable isotopes from collagen (Ambrose et al. 1997; Commendador et al. 2019; Fenner et al. 2015; Jones and Quinn 2009) and no Pacific studies have reported correlations between $\delta^{13}C_{carbonate}$ and $\delta^{13}C_{collagen}$. When plotting exported data from tables and supplementary information from these studies, Fenner et al.

(2015) did not analyze stable isotopes from carbonate and collagen on the same samples and so comparisons are impossible; the Marianas island samples analyzed by Ambrose et al. (1997) have an insignificant negative correlation r(14) = -0.064, p = 0.812, the Jones and Quinn (2009) Fijian samples have an insignificant positive correlation, r(7) = 0.361, p = 0.34, and Commendador et al. (2019) have a significant positive relationship between their Rapa Nui sample values, r(26) = 0.489, p = 0.008.

Both $\delta^{13}C_{collagen}$ and $\delta^{13}C_{carbonate}$ values are typically utilized in bioarchaeological studies to differentiate between C_3 versus C_4/marine resources. The main difference in collagen and carbonate values from bone and tooth samples are a result of how carbon atoms are differentially routed from diet during synthesis of these bulk tissues, with collagen dominated by dietary protein and carbonate largely reflective of whole diet (Fernandes et al. 2012). A negative correlation between $\delta^{13}C_{collagen}$ and $\delta^{13}C_{carbonate}$ in an ancient Pacific context could imply diets along a spectrum with two end member diets: the first type of diet would be high inputs of marine-derived protein and low-protein terrestrial foods (e.g., marine animals and starchy root vegetables) that create a relatively higher $\delta^{13}C_{collagen}$ value and lower $\delta^{13}C_{carbonate}$ value, and high inputs of terrestrial protein supplemented with low-protein marine foods (e.g., terrestrial animal flesh and low trophic reef foods such as sea weed, seagrass, and first-level consumers). Most of the $\Delta^{13}C$ data is below 4.5‰ (53/68, 78%), in agreement with the former interpretation of a general diet of marine proteins with terrestrial C_3 energy sources. With relatively few comparative studies analyzing carbonate and collagen in tandem, future work might elucidate what a negative correlation implies in Pacific context.

4. CONCLUSIONS

The differences in diet between social status groups found in adults in previous research, thought to be a result of socially mediated access to certain food groups, are not present in childhood. Evidence of extreme physiological stress was not observed in collagen stable isotope values in these survivors of childhood as negative covariance in values across time. The strong positive covariance between $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ demonstrates the need for the study of total diet in the Pacific using $\delta^{13}C_{carbonate}$, not just collagen isotope data.

Though the dataset for this pilot study is small, we can see the potential of continuing this research using the Taumako assemblage, analyzing the other 79 adults as well as the subadults old enough to have completed first molar formation but who did not survive into adulthood in order to compare survivors and non-survivors of childhood. Expanding the study to include third molars to investigate adolescence/early adulthood would provide a longer dietary life history of the Taumako individuals, as utilized by Eerkens et al. (2019) in ancient American Samoa. The use of deciduous molars has yielded information relating to the *in utero* environment and maternal stress in those who did not survive childhood in archaeologically-derived individuals in the Atacama desert in Chile (King et al. 2018), and would also provide valuable information for investigating the longitudinal evidence of infant and child feeding practices in those members of the prehistoric community that did not survive to adolescence. Further work needs to be undertaken in refining the slicing process to match the 1mm dentin sections obtained in previous research (Beaumont et al. 2014), but 2mm sections showed temporal resolution unavailable using bulk sampling methods of dentin or bone. This modification to the Beaumont method maximizes data yields while minimizing sample destruction, such as conducting multiple analytical suites on a single molar. With the dentin depositing in layers of convex curvature (Czermak et al. early view; Eerkens et al. 2011), transverse slices cutting through multiple layers from crown to root might actually represent different spaces of time, making the inference that each section represents an equal amount of growth untrue. Cutting out plug transects following the new method suggested by Czermak et al. (early view) might strengthen future interpretations, although the smaller sample sizes are likely to fail in instances of poor preservation where the dentin disintegrated as it did for many of the apices of the Taumako teeth. The integration of $\delta^{2}H$, which shows promising interpretative value for investigating infant feeding and weaning practices (Ryan et al. 2020) and would further maximize data collection in proportion to destructive technique.

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REFERENCES

AlQahtani SJ, Hector MP, and Liversidge HM. 2010. Brief communication: The London atlas of human tooth development and eruption. American Journal of Physical Anthropology 142(3):481-490.

Ambrose SH. 1990. Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. Journal of Archaeological Science 17:431-451.

Ambrose SH, Butler BM, Hanson DB, Hunter-Anderson RL, and Krueger HW. 1997. Stable isotopic analysis of human diet in the Marianas Archipelago, Western Pacific. American Journal of Physical Anthropology 104(3):343-361.

Ambrose SH, and Norr L. 1992. On Stable Isotopic Data and Prehistoric Subsistence in the Soconusco Region. Current Anthropology 33(4):401-404.

Ambrose SH, and Norr L. 1993. Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. In: Lambert JB, and Grupe G, editors. Prehistoric Human Bone. Berlin, Germany: Springer. p 1-37.

Baković M, Vreča P, and Mayer D. 2017. Case of Fatal Starvation: Can Stable Isotope Analysis Serve to Support Morphological Diagnosis and Approximate the Length of Starvation? Journal of Forensic Sciences 62(1):258-264.

Balasse M, Smith AB, Ambrose SH, and Leigh SR. 2003. Determining Sheep Birth Seasonality by Analysis of Tooth Enamel Oxygen Isotope Ratios: The Late Stone Age Site of Kasteelberg (South Africa). Journal of Archaeological Science 30(2):205-215.

Barrau J. 1961. Subsistence Agriculture in Polynesia and Micronesia. Honolulu, Hawaii: Bernice P. Bishop Museum.

Bayard DT. 1976. The cultural relationships of the Polynesian outliers. Dunedin, New Zealand: University of Otago, Department of Anthropology.

Beaglehole JC, editor. 1967. Journals of Captain James Cook on his voyages of discovery. Cambridge, United Kingdom: Cambridge University Press.

Beasley MM, Bartelink EJ, Taylor L, and Miller RM. 2014. Comparison of transmission FTIR, ATR, and DRIFT spectra: implications for assessment of bone bioapatite diagenesis. Journal of Archaeological Science 46:16-22.

Beaumont J, Atkins E-C, Buckberry J, Haydock H, Horne P, Howcroft R, Mackenzie K, and Montgomery J. 2018. Comparing apples and oranges: Why infant bone collagen may not reflect dietary intake in the same way as dentine collagen. American Journal of Physical Anthropology 167(3):524-540.

Beaumont J, Gledhill A, Lee-Thorp J, and Montgomery J. 2013. Childhood diet: A closer examination of the evidence from dental tissues using stable isotope analysis of incremental human dentine. Archaeometry Bulletin of the Research Laboratory for Archaeology and the History of Art, Oxford University 55(2):277-295.

Beaumont J, Gledhill A, and Montgomery J. 2014. Isotope analysis of incremental human dentine: towards higher temporal resolution. Bulletin of the International Association for Paleodontology 8(2):212-223.

Beaumont J, and Montgomery J. 2015. Oral histories: a simple method of assigning chronological age to isotopic values from human dentine collagen. Annals of Human Biology 42(4):407-414.

Beaumont J, and Montgomery J. 2016. The Great Irish Famine: Identifying Starvation in the Tissues of Victims Using Stable Isotope Analysis of Bone and Incremental Dentine Collagen. PloS One 11(8):e0160065.

Beaumont J, Montgomery J, Buckberry J, and Jay M. 2015. Infant mortality and isotopic complexity: New approaches to stress, maternal health, and weaning. American Journal of Physical Anthropology 157(3):441-457.

Bell FLS. 1931. The Place Of Food In The Social Life Of Central Polynesia. Oceania 2(2):117-135.

Bocherens H, and Drucker D. 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. International Journal of Osteoarchaeology 13(1-2):46-53.

Brown TA, Nelson DE, Vogel JS, and Southon JR. 1988. Improved collagen extraction by modified Longin method. Radiocarbon 30(2):171-177.

Buckley HR. 2016. Health and Disease in the Prehistoric Pacific Islands. Oxford, UK: British Archaeological Reports.

Buckley HR, and Tayles N. 2003a. Skeletal pathology in a prehistoric Pacific Island sample: Issues in lesion recording, quantification, and interpretation. American Journal of Physical Anthropology 122(4):303-324.

Buckley HR, and Tayles NG. 2003b. The functional cost of tertiary yaws (Treponema pertenue) in a prehistoric Pacific Island skeletal sample. Journal of Archaeological Science 30(10):1301-1314.

Cardoso HFV. 2007. Accuracy of developing tooth length as an estimate of age in human skeletal remains: The deciduous dentition. Forensic Science International 172(1):17-22.

Commendador AS, Finney BP, Fuller BT, Tromp M, and Dudgeon JV. 2019. Multiproxy isotopic analyses of human skeletal material from Rapa Nui: Evaluating the evidence from carbonates, bulk collagen, and amino acids. American Journal of Physical Anthropology 169(4):714-729.

Czermak A, Fernández-Crespo T, Ditchfield PW, and Lee-Thorp JA. early view. A guide for an anatomically sensitive dentine microsampling and age-alignment approach for human teeth isotopic sequences. American Journal of Physical Anthropology n/a(n/a):e24126.

Danforth ME. 1999. Nutrition and Politics in Prehistory. Annual Review of Anthropology 28(1):1-25.

Darmon N, and Drewnowski A. 2008. Does social class predict diet quality? The American Journal of Clinical Nutrition 87(5):1107-1117.

Davenport W. 1962. Red-Feather Money. Scientific American 206(3):94-104.

Davenport WH. 1968. Social organization notes on the northern Santa Cruz Islands : the Duff Islands (Taumako). Berlin, Germany: Baessler-Archiv.

Davidson JM. 2012. Intrusion, integration and innovation on small and not-so-small islands with particular reference to Samoa. Archaeology in Oceania 47(1):1-13.

de Luca A, Boisseau N, Tea I, Louvet I, Robins RJ, Forhan A, Charles M-A, and Hankard R. 2012. $\delta^{15}N$ and $\delta^{13}C$ in hair from newborn infants and their mothers: a cohort study. Pediatric Research 71:598.

DeNiro MJ. 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature 317(6040):806-809.

DeNiro MJ, and Epstein S. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochimica et Cosmochimica Acta 42(5):495-506.

Dettwyler KA. 2004. When to Wean: Biological Versus Cultural Perspectives. Clinical Obstetrics and Gynecology 47(3):712-723.

Eerkens JW, Bartelink EJ, Bartel J, and Johnson PR. 2019. Isotopic Insights into Dietary Life History, Social Status, and Food Sharing in American Samoa. American Antiquity:1-17.

Eerkens JW, Berget AG, and Bartelink EJ. 2011. Estimating weaning and early childhood diet from serial micro-samples of dentin collagen. Journal of Archaeological Science 38(11):3101-3111.

Ella S. 1899. The war of Tonga and Samoa and origin of the name Malietoa. The Journal of the Polynesian Society 8(4(32)):231-234.

Feinberg R, and Scaglion R. 2012. Introduction: The Polynesian Outliers. In: Feinberg R, and Scaglion R, editors. Polynesian Outliers: The State of the Art. Pittsburgh, PA: University of Pittsburgh. p 1-16.

Fenner JN, Clark G, Cressey A, Valentin F, Olesen SH, and Armstrong R. 2015. Isotopic uniformity and segregation in Tongan mounds. Journal of Archaeological Science: Reports 2(June 2015):644-653.

Fernandes R, Nadeau M-J, and Grootes P. 2012. Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. Archaeological and Anthropological Sciences 4(4):291-301.

Field JS, Cochrane EE, and Greenlee DM. 2009. Dietary change in Fijian prehistory: isotopic analyses of human and animal skeletal material. Journal of Archaeological Science 36(7):1547-1556.

Firth R. 1936. We, the Tikopia. London, England: George Allen & Unwin Ltd.

Firth R. 1939. Primitive Polynesian Economy. London, UK: Routledge.

France CAM, and Owsley DW. 2015. Stable Carbon and Oxygen Isotope Spacing Between Bone and Tooth Collagen and Hydroxyapatite in Human Archaeological Remains. International Journal of Osteoarchaeology 25(3):299-312.

France CAM, Sugiyama N, and Aguayo E. 2020. Establishing a preservation index for bone, dentin, and enamel bioapatite mineral using ATR-FTIR. Journal of Archaeological Science: Reports 33:102551.

Froehle AW, Kellner CM, and Schoeninger MJ. 2010. FOCUS: effect of diet and protein source on carbon stable isotope ratios in collagen: follow up to Warinner and Tuross (2009). Journal of Archaeological Science 37(10):2662-2670.

Froehle AW, Kellner CM, and Schoeninger MJ. 2012. Multivariate carbon and nitrogen stable isotope model for the reconstruction of prehistoric human diet. American Journal of Physical Anthropology 147(3):352-369.

Fry B, Lutes R, Northam M, Parker PL, and Ogden J. 1982. A $^{13}C/^{12}C$ comparison of food webs in Caribbean seagrass meadows and coral reefs. Aquatic Botany 14(0):389-398.

Fuller BT, Fuller JL, Harris DA, and Hedges REM. 2006. Detection of breastfeeding and weaning in modern human infants with carbon and nitrogen stable isotope ratios. American Journal of Physical Anthropology 129(2):279-293.

Fuller BT, Richards MP, and Mays SA. 2003. Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy. Journal of Archaeological Science 30(12):1673-1684.

Geyh MA. 2001. Bomb Radiocarbon Dating Of Animal Tissues And Hair.

Goldberg M, Kulkarni AB, Young M, and Boskey A. 2011. Dentin: structure, composition and mineralization. Frontiers in bioscience (Elite edition) 3:711-735.

Greenhill SJ, and Clark R. 2011. POLLEX-Online: The Polynesian lexicon project online. Oceanic Linguistics 50(2):551-559.

Hedges REM, Clement JG, Thomas CDL, and O'Connell TC. 2007. Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. American Journal of Physical Anthropology 133(2):808-816.

Herrscher E, Fenner J, N., Valentin F, Clark G, Reepmeyer C, Bouffandeau L, and André G. 2018. Multi-isotopic analysis of first Polynesian diet (Talasiu, Tongatapu, Kingdom of Tonga). Journal of Archaeological Science: Reports 18:308 - 317.

Hobson KA, and Clark RG. 1992. Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. Condor:189-197.

Hoefs J. 2009. Stable Isotope Geochemistry. Berlin, Germany: Springer-Verlag.

Hollund H, Ariese F, Fernandes R, Jans M, and Kars H. 2013. Testing an alternative high-throughput tool for investigating bone diagenesis: FTIR in attenuated total reflection (ATR) mode. Archaeometry 55(3):507-532.

Intoh M. 1999. Cultural contacts between Micronesia and Melanesia. In: Galipaud J-C, and Lilley I, editors. The Pacific from 5000 to 2000 BP: Colonisation and transformations. Port Vila, Vanuatu: Éditions det IRD. p 407-422.

Jay M. 2009. Breastfeeding and Weaning Behaviour in Archaeological Populations: Evidence from the Isotopic Analysis of Skeletal Materials. Childhood in the Past 2(1):163-178.

Jay M, Fuller BT, Richards MP, Knüsel CJ, and King SS. 2008. Iron Age breastfeeding practices in Britain: Isotopic evidence from Wetwang Slack, East Yorkshire. American Journal of Physical Anthropology 136(3):327-337.

Jim S, Ambrose SH, and Evershed RP. 2004. Stable carbon isotopic evidence for differences in the dietary origin of bone cholesterol, collagen and apatite: implications for their use in palaeodietary reconstruction. Geochimica et Cosmochimica Acta 68(1):61-72.

Jones S. 2009. Food and Gender in Fiji: Ethnoarchaeological explorations. Lanham, MD: Lexington Books.

Jones S, and Quinn RL. 2009. Prehistoric Fijian diet and subsistence: integration of faunal, ethnographic, and stable isotopic evidence from the Lau Island Group Journal of Archaeological Science 36(12):2742 - 2754.

Katzenberg MA, Saunders SR, and Fitzgerald WR. 1993. Age differences in stable carbon and nitrogen isotope ratios in a population of prehistoric maize horticulturists. American Journal of Physical Anthropology 90(3):267-281.

Katzenberg MA, and Weber A. 1999. Stable Isotope Ecology and Palaeodiet in the Lake Baikal Region of Siberia. Journal of Archaeological Science 26(6):651-659.

Keegan WF, and DeNiro MJ. 1988. Stable Carbon- and Nitrogen-Isotope Ratios of Bone Collagen Used to Study Coral-Reef and Terrestrial Components of Prehistoric Bahamian Diet. American Antiquity 53(2):320-336.

Kellner CM, and Schoeninger MJ. 2007. A simple carbon isotope model for reconstructing prehistoric human diet. American Journal of Physical Anthropology 133(4):1112-1127.

Kendall E. 2016. The "Terrible Tyranny of the Majority": Recognising Population Variability and Individual Agency in Past Infant Feeding Practices. In: Powell L, Southwell-Wright W, and Gowland R, editors. Care in the Past: Archaeological and Interdisciplinary Perspectives. Oxford: Oxbow Books. p 39-51.

Kennedy GE. 2005. From the ape's dilemma to the weanling's dilemma: early weaning and its evolutionary context. Journal of Human Evolution 48(2):123-145.

Kinaston R, Bedford S, Richards M, Hawkins S, Gray A, Jaouen K, Valentin F, and Buckley H. 2014a. Diet and Human Mobility from the Lapita to the Early Historic Period on Uripiv Island, Northeast Malakula, Vanuatu. PloS One 9(8):e104071.

Kinaston R, Buckley H, Gray A, Shaw B, and Mandui H. 2013a. Exploring subsistence and cultural complexes on the south coast of Papua New Guinea using palaeodietary analyses. Journal of Archaeological Science 40(2):904-913.

Kinaston R, Buckley H, Valentin F, Bedford S, Spriggs M, Hawkins S, and Herrscher E. 2014b. Lapita Diet in Remote Oceania: New Stable Isotope Evidence from the 3000-Year-Old Teouma Site, Efate Island, Vanuatu. PloS One 9(3):e90376.

Kinaston RL, and Buckley HR. 2017. Isotopic insights into diet and health at the site of Namu, Taumako Island, Southeast Solomon Islands. Archaeological and Anthropological Sciences 9(7):1405-1420.

Kinaston RL, Buckley HR, and Gray A. 2013b. Diet and social status on Taumako, a Polynesian outlier in the Southeastern Solomon Islands. American Journal of Physical Anthropology 151(4):589-603.

King CL, Halcrow SE, Millard AR, Gröcke DR, Standen VG, Portilla M, and Arriaza BT. 2018. Let's talk about stress, baby! Infant-feeding practices and stress in the ancient Atacama desert, Northern Chile. American Journal of Physical Anthropology 166(1):139-155.

Kirch PV. 1984a. Evolution of the Polynesian Chiefdoms. Cambridge & New York: Cambridge University Press.

Kirch PV. 1984b. The Polynesian Outliers: Continuity, change, and replacement. The Journal of Pacific History 19(4):224-238.

Kirch PV. 1997. The Lapita peoples: ancestors of the Oceanic world. Cambridge, Massachusetts: Blackwell Publishers.

Kirch PV, and Green RC. 2001. Hawaiki, Ancestral Polynesia: An Essay in Historical Anthropology. Cambridge, UK: Cambridge University Press.

Kirch PV, and Hunt TL. 1997. Historical ecology in the Pacific Islands: prehistoric environmental and landscape change. New Haven: Yale University Press.

Koch G. 1971. Materielle Kultur der Santa Cruz-Inseln: unter besonderer Berucksichtigung der Riff-Inseln. Berlin, Germany: Museum fur Volkerkunde.

Kramer MS, and Kakuma R. 2004. The Optimal Duration of Exclusive Breastfeeding. In: Pickering LK, Morrow AL, Ruiz-Palacios GM, and Schanler RJ, editors. Protecting Infants through Human Milk: Advancing the Scientific Evidence. Boston, MA: Springer US. p 63-77.

Lahtinen M. 2017. Isotopic Evidence for Environmental Adaptation in Medieval Iin Hamina, Northern Finland. Radiocarbon 59(4):1117-1131.

Leach BF, and Davidson J. 2008. Archaeology on Taumako: A Polynesian Outlier in the Eastern Solomon Islands. Dunedin, New Zealand: New Zealand Journal of Archaeology Special Publication.

Leach F, Quinn C, Morrison J, and Lyon G. 2003. The use of multiple isotope signatures in reconstructing prehistoric human diet from archaeological bone from the Pacific and New Zealand. New Zealand Journal of Archaeology 23:31-98.

Leach H. 2003. Did East Polynesians Have a Concept of Luxury Foods? World Archaeology 34(3): 442-457.

Lee-Thorp JA. 2008. On Isotopes and Old Bones. Archaeometry Bulletin of the Research Laboratory for Archaeology and the History of Art, Oxford University 50(6):925-950.

Lee-Thorp JA, Sealy JC, and van der Merwe NJ. 1989. Stable carbon isotope ratio differences between bone collagen and bone apatite, and their relationship to diet Journal of Archaeological Science 16(6):585 - 599.

Lewis ME. 2007. The bioarchaeology of children. Cambridge, UK: Cambridge University Press.

Loftus E, and Sealy J. 2012. Technical note: Interpreting stable carbon isotopes in human tooth enamel: An examination of tissue spacings from South Africa. American Journal of Physical Anthropology 147(3):499-507.

Longin R. 1971. New method of collagen extraction for radiocarbon dating. Nature 230(5291):241-242.

Mariner W, and Martin J. 1827. An account of the natives of the Tonga Islands in the South Pacific Ocean: with an original grammar and vocabulary of their language. Edinburgh, Scotland: Constable and Hurst Chance.

Marshall JD, Brooks JR, and Lajtha K. 2007. Sources of variation in the stable isotopic composition of plants. In: Michener R, and Lajtha K, editors. Stable Isotopes in Ecology and Environmental Science. Malden, Maryland: Blackwell Publishing Ltd. p 22-60.

Mekota A-M, Grupe G, Ufer S, and Cuntz U. 2006. Serial analysis of stable nitrogen and carbon isotopes in hair: monitoring starvation and recovery phases of patients suffering from anorexia nervosa. Rapid Communications in Mass Spectrometry 20(10):1604-1610.

Minagawa M, and Wada E. 1984. Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between $\delta^{15}N$ and animal age. Geochimica et Cosmochimica Acta 48(5):1135-1140.

Nanci A. 2013. Ten Cate's Oral Histology: Development, Structure, and Function. St. Louis: Elsevier.

Neuberger FM, Jopp E, Graw M, Püschel K, and Grupe G. 2013. Signs of malnutrition and starvation—Reconstruction of nutritional life histories by serial isotopic analyses of hair. Forensic Science International 226(1):22-32.

Nunn PD, Ishimura T, Dickinson WR, Katayama K, Thomas FR, Kumar R, Matararaba S, Davidson J, and Worthy TH. 2007. The Lapita occupation at Naitabale, Moturiki Island, central Fiji. Asian Perspectives 46(1):96-132.

Oliver DL. 1989. Oceania: the native cultures of Australia and the Pacific Islands. Honolulu, Hawai'i: University of Hawai'i Press.

Passey BH, Robinson TF, Ayliffe LK, Cerling TE, Sponheimer M, Dearing MD, Roeder BL, and Ehleringer JR. 2005. Carbon isotope fractionation between diet, breath CO_2, and bioapatite in different mammals. Journal of Archaeological Science 32(10):1459-1470.

Perkins MJ, McDonald RA, van Veen FJF, Kelly SD, Rees G, and Bearhop S. 2014. Application of Nitrogen and Carbon Stable Isotopes (δ^{15}N and δ^{13}C) to Quantify Food Chain Length and Trophic Structure. PloS One 9(3):e93281.

Pestle WJ, and Colvard M. 2012. Bone collagen preservation in the tropics: a case study from ancient Puerto Rico. Journal of Archaeological Science 39(7):2079-2090.

Phaff B, Burley DV, and Richards M. 2015. Dietary isotope patterns and their social implications in a prehistoric human population from Sigatoka, Fiji. Journal of Archaeological Science: Reports.

Pollock NJ. 1992. These Roots Remain: Food Habits in Islands of Central and Eastern Pacific Since Western Contact. Honolulu: Institute for Polynesian Studies.

Quirós PFd, and Markham C. 1904. The Voyages of Pedro Fernandez de Quiros, 1595-1606. 2 vols. London, UK: Hakluyt Society.

Reynard LM, and Tuross N. 2015. The known, the unknown and the unknowable: weaning times from archaeological bones using nitrogen isotope ratios. Journal of Archaeological Science 53(0):618-625.

Richards MP, and Hedges REM. 1999. Stable Isotope Evidence for Similarities in the Types of Marine Foods Used by Late Mesolithic Humans at Sites Along the Atlantic Coast of Europe. Journal of Archaeological Science 26(6):717 - 722.

Ritchie J, and Ritchie J. 1979. Growing up in Polynesia. Boston, MA: George Allen and Unwin.

Ryan SE, Reynard LM, Pompianu E, van Dommelen P, Murgia C, Subirà ME, and Tuross N. 2020. Growing up in Ancient Sardinia: Infant-toddler dietary changes revealed by the novel use of hydrogen isotopes (δ2H). PloS One 15(7):e0235080.

Sandberg PA, Sponheimer M, Lee-Thorp J, and Van Gerven D. 2014. Intra-tooth stable isotope analysis of dentine: A step toward addressing selective mortality in the reconstruction of life history in the archaeological record. American Journal of Physical Anthropology 155(2):281-293.

Schoeninger MJ, DeNiro MJ, and Tauber H. 1983. Stable Nitrogen Isotope Ratios of Bone Collagen Reflect Marine and Terrestrial Components of Prehistoric Human Diet. Science 220(4604):1381-1383.

Sharp ZD. 2017. Principles of Stable Isotope Geochemistry, Second Edition. Published Online.

Smith BH. 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. American Journal of Physical Anthropology 63(1):39-56.

Smith EK, Pestle WJ, Clarot A, and Gallardo F. 2017. Modeling Breastfeeding and Weaning Practices (BWP) on the Coast of Northern Chile's Atacama Desert During the Formative Period. The Journal of Island and Coastal Archaeology 12(4):558-571.

Stantis C, Buckley HR, Kinaston RL, Nunn PD, Jaouen K, and Richards MP. 2016a. Isotopic evidence of human mobility and diet in a prehistoric/protohistoric Fijian coastal environment (c. 750–150 BP). American Journal of Physical Anthropology 159(3):478-495.

Stantis C, Kinaston RL, Richards MP, Davidson JM, and Buckley HR. 2015. Assessing Human Diet and Movement in the Tongan Maritime Chiefdom Using Isotopic Analyses. PloS One 10(3):e0123156.

Stantis C, Schutkowski H, and Sołtysiak A. 2020. Reconstructing breastfeeding and weaning practices in the Bronze Age Near East using stable nitrogen isotopes. American Journal of Physical Anthropology 172(1):58-69.

Stantis C, Tayles N, Kinaston RL, Cameron C, Nunn PD, Richards MP, and Buckley HR. 2016b. Diet and subsistence in Remote Oceania: an analysis using oral indicators of diet. In: Oxenham MF, and Buckley HR, editors. The Routledge Handbook of Bioarchaeology in Southeast Asia and the Pacific. London, UK: Routledge.

Stuart-Macadam P. 2017. Breastfeeding in prehistory. Stuart-Macadam P, Dettwyler KA, eds.

Szulc P, Seeman E, and Delmas P. 2000. Biochemical measurements of bone turnover in children and adolescents. Osteoporosis International 11(4):281-294.

Thomson BH. 1902. Savage Island; an account of a sojourn in Niué and Tonga. London, UK: J. Murray.

Tieszen LL. 1991. Natural variations in the carbon isotope values of plants: Implications for archaeology, ecology, and paleoecology. Journal of Archaeological Science 18(3):227-248.

Tieszen LL, Boutton TW, Tesdahl K, and Slade NA. 1983. Fractionation and turnover of stable carbon isotopes in animal tissues: implications for $\delta^{13}C$ analysis of diet. Oecologia 57(1-2):32-37.

Tieszen LL, and Fagre T. 1993. Effect of diet quality and composition on the isotopic composition of respiratory CO 2, bone collagen, bioapatite, and soft tissues. Prehistoric human bone: Springer. p 121-155.

Tsutaya T. 2017. Post-weaning diet in archaeological human populations: A meta-analysis of carbon and nitrogen stable isotope ratios of child skeletons. American Journal of Physical Anthropology 163(3):546-557.

Tsutaya T, and Yoneda M. 2013. Quantitative Reconstruction of Weaning Ages in Archaeological Human Populations Using Bone Collagen Nitrogen Isotope Ratios and Approximate Bayesian Computation. PloS One 8(8):e72327.

Tsutaya T, and Yoneda M. 2015. Reconstruction of breastfeeding and weaning practices using stable isotope and trace element analyses: A review. American Journal of Physical Anthropology 156:2-21.

Twiss K. 2012. The Archaeology of Food and Social Diversity. Journal of Archaeological Research 20(4):357-395.

Valentin F, Bocherens H, Gratuze B, and Sand C. 2006. Dietary patterns during the late prehistoric/historic period in Cikobia island (Fiji): insights from stable isotopes and dental pathologies. Journal of Archaeological Science 33(10):1396-1410.

Valentin F, Herrscher E, Petchey F, and Addison DJ. 2011. An analysis of the last 1000 years human diet on Tutuila (American Samoa) using carbon and nitrogen stable isotope data. American Antiquity 76(3):473-486.

Webb EC, Lewis J, Shain A, Kastrisianaki-Guyton E, Honch NV, Stewart A, Miller B, Tarlton J, and Evershed RP. 2017. The influence of varying proportions of terrestrial and marine dietary protein on the stable carbon-isotope compositions of pig tissues from a controlled feeding experiment. STAR: Science & Technology of Archaeological Research 3(1):28-44.

Whistler WA. 2007. Plants of the canoe people: an ethnobotanical voyage through Polynesia. Honolulu, Hawai'i: National Tropical Botanical Garden.

Wood JW, Milner GR, Harpending HC, Weiss KM, Cohen MN, Eisenberg LE, Hutchinson DL, Jankauskas R, Česnys G, Katzenberg MA et al. . 1992. The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples [and Comments and Reply]. Current Anthropology 33(4):343-370.

Zohary T, Erez J, Berman-Frank I, and Stiller M. 1994. Seasonality of stable carbon isotopes within the pelagic food web of Lake Kinneret. Limnology and Oceanography 39(5):1030-1043.

Tables

Table 1. Individuals sampled for this study. Wealth index score by Leach and Davidson (2008), age and sex estimated by Buckley (2016). Low wealth = 1, high wealth > 1000.

Burial	Wealth Index Score	Age	Sex
1.1	1411	Young Adult	Male
2	1	Young Adult	Female
11.1	1	Young Adult	Male
20	1	Middle-aged Adult	Female
21	1001	Young Adult	Female
32	1513	12 years	Indeterminate
34	1	Young Adult	Male
54	1043	Young Adult	Female
57	1	Middle-aged Adult	Female
68	1	Young Adult	Male
70	1	Young Adult	Female
84	1226	Young Adult	Female
88	2713	Middle-aged Adult	Female
91	1371	Young Adult	Female
104	1	Old Adult	Male
108	2205	Young Adult	Male
109	1	Middle-aged Adult	Female
151	5030	15.5 years	Indeterminate
159	1253	Middle-aged Adult	Female
194	1309	Young Adult	Male

Table 2. Approximate age range captured for each 2mm section of tooth cut

Dentin Section	Approximate age range
1 (top of crown)	0 – 18 months
2	18 – 36 months
3	3 – 4.5 years

4	4.5 – 6 years
5	6 – 7.5 years
6	7.5 – 9 years
7 (apex)	9 – 10 years

936

937 Table 3. Summary statistics of the tooth collagen and carbonate stable isotope values, by tooth section
938 and all sections combined.

	$\delta^{13}C_{collagen}$		**$\delta^{15}N_{collagen}$**			**$\delta^{13}C_{carbonate}$**		
	Mean	1 SD	Mean	1 SD	Collagen Samples *N*	Mean	1 SD	Carbonate Samples *N*
Section 1	-16.67	0.48	11.21	0.62	20	-13.37	1.06	11
Section 2	-16.64	0.54	11	0.64	20	-12.8	0.98	15
Section 3	-16.51	0.57	10.87	0.73	19	-13.09	0.82	20
Section 4	-16.56	0.74	10.76	0.53	14	-13.06	0.72	20
Section 5	-16.53	0.96	10.96	1.22	8	-12.97	0.71	19
Section 6	-15.31	---	12.2	---	1	-12.9	0.89	9
Section 7	---	---	---	---	0	-12.87	1.32	3
All	-16.57	0.62	10.99	0.72	82	-13.02	0.85	97

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