Comparing activity restriction and habitat creation approaches in Marine Protected Areas (MPAs): a Bayesian belief network model approach.

Ellie Vincent

Award for which degree is submitted: Masters by Research

Faculty of Science and Technology

Bournemouth University

Submission: March 2025

Copyright statement

This copy of the thesis has been supplied on condition that anyone who consults it is understood to recognise that its copyright rests with its author, and due acknowledgement must always be made of the use of any material contained in, or derived from, this thesis.

Data availability statement

The data that support the findings of this study are available within the article and its supplementary materials.

Abstract

Marine Protected Areas (MPAs) often fail to meet their objectives due to inadequate protection, lack of user compliance and insufficient governance. Whilst typical MPA usage restrictions such as fishing bans are often effective for ecological success, such approaches can fail in meeting socioeconomic objectives due to negative impacts on the livelihoods of those dependent on MPA resources. These issues can further reduce MPA effectiveness through loss of community support. Additionally, suitable governance is often lacking, preventing even well-designed MPAs from operating successfully due to absence of enforcement, cooperation, education and funding.

This study considers the concept of habitat creation as an alternative MPA management approach to fishing restrictions, as a potential tool for reducing ecological and socioeconomic trade-offs within MPAs. Through actively restoring existing habitats or introducing low trophic-level aquaculture as novel habitat, benefits to associated marine life can create increased fish stocks and tourism opportunities, with benefit to local economies. Using complex system modelling, this study compares habitat creation with restrictive fishing, in two ecologically and socioeconomically distinct MPAs: Nusa Penida, Indonesia, and Lyme Bay, UK, and considers the appropriate governance required for achieving such approaches.

Whilst fishing restrictions at both sites resulted in predicted improvements to ecosystems but reduced employment, deeming them less effective, enhancing existing habitats in Nusa Penida, resulted in predicted reductions in trade-offs, through increased fish stocks, biodiversity, employment, and community support for MPA policies. Novel habitat creation, in the form of mussel farms in Lyme Bay, demonstrated similar positive effects. The need for some fishing restrictions in both scenarios was recognised, however, these were considered to be reduced in comparison to traditional MPA fishing restrictions. While habitat creation proved successful, its feasibility was considered dependent on MPA characteristics such as aquacultural capacity, fishing culture, tourism potential, and alternative employment options.

Both habitat creation scenarios demonstrated the opportunity to diverge from limited state funding, through governance that enables private sector funding or carbon/nature credit systems, and active restoration projects demonstrated positive results with less need for legal governance in comparison to restrictive approaches. This study shows support for alternative approaches for marine nature protection, which in some cases may be easier to implement and gain support for than approaches such as fishing restrictions.

Contents

List of figures

List of Tables

Acknowledgements

I wish to thank my supervisors, Richard Stafford, Stephen Axon and Peter Jones for their support, time and knowledge throughout this research.

1. Introduction

1.1 The role of MPAs

Ocean ecosystems provide food provisions and ecosystem services to billions of people worldwide, making them vital for the future of humankind. Habitats such as seagrass meadows, mangrove forests and coral reefs provide shelter and food for marine organisms (Whitfield 2017; Damastuti et al. 2022; Ginantra and Sunda 2023), supporting biodiversity and providing the facilitation of sustainable fish stocks (Maggs et al. 2013). Many of these systems facilitate carbon sequestration (Tan et al. 2020), provide coastal protection (Harris et al. 2018; Tan et al. 2020; Dinu et al. 2023), and improve water quality (Valiela and Cole 2002; Lin and Dushoff 2004), which in turn help the habitats and marine life around them (Bhadarka et al. 2023). Some marine spaces offer the opportunity for aquatic agriculture, providing employment and goods to local people (Hossain et al. 2021), and for many of these habitats, the biodiversity and natural assets they provide create recreational and wellbeing benefits to coastal communities and those appreciative of nature (Ginantra and Sundra 2023).

However, these ecosystems are failing due to the continuation of human overexploitation and damage to the marine environment. Fishing activity continues to deplete fish stocks and biodiversity at an unsustainable rate (Food and Agriculture Organization of the United Nations [FAO] 2024), through overexploitation of target species, bycatch of non-target species and disruptive fishing techniques (Carneiro and Martins 2022). Human induced pollutants such as nutrients, pathogens and litter threaten marine organisms through entanglement and physiological impacts (Islam and Tanaka 2004; Stelfox et al. 2016; Celis-Hernandez et al. 2022), and many recreational activities such as SCUBA diving and the use of personal watercrafts cause disturbance, boat strikes to megafauna and trampling damage to benthic habitats (Davenport and Davenport 2006; Hayes et al. 2017).

In efforts to protect marine ecosystems from these threats came the designation of Marine Protected Areas (MPAs), which are allocated marine spaces used to enhance biodiversity and sustainable use of marine resources, usually through the restriction of harmful anthropogenic activities such as fishing, anchoring, or

recreational use (Leenhardt et al. 2015; O'Leary et al. 2016; Di Cintio et al. 2023). MPAs have been established for as long as 100 years, evolving from localised conservation efforts to a global strategy for ocean protection (Humphreys and Clark 2020). The Rio 'Earth Summit' in 1992 set the first global MPA area target of 10%, and after failing to meet this target within the deadline assigned, was replaced with The Aichi Biodiversity Target, requiring 10% coverage by 2020 (Humphreys and Clark 2020). Currently, Target 3 of the Kunming-Montreal Global Biodiversity Framework, which was developed during the 15th Conference of the Parties to the United Nations Convention on Biological Diversity (CBD) in 2022, implements a target to all participating nations to protect 30% of marine, coastal, terrestrial, and inland water habitats by 2030 (CBD 2022). Reports show that an additional 1.77 million km² of marine and coastal waters have been protected since 2020, but global coverage remains at 8.4%. Whilst progress has been made, considerable increase is required in order to reach the target (UN Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] and The International Union for Conservation of Nature [IUCN] 2024).

1.2 The failure of MPAs

Despite MPAs increasing worldwide, many fail in reality to achieve conservation objectives (Edgar et al. 2014; Spalding et al. 2016; Di Cintio et al. 2023). MPA objectives and regulations are determined by managing authorities, which can range from governments and other state actors, private organisations, Indigenous communities and non-government organisations (NGOs) (Worboys and Trzyna 2015). Whilst management frameworks that aim to guide effective MPA management exist (Grorud-Colvert et al. 2021), there is no specific criteria on the protection levels required for MPA status, meaning designs vary widely. Because of this, many MPAs remain ineffective (Rife et al. 2013), with recent research suggesting potentially

>70% of MPAs are partially or totally failing to achieve their conservation goals (Di Cintio et al. 2023).

1.2.1 Inadequate protection

MPA failures often occur when applied regulations offer inadequate ecosystem protection (Edgar et al. 2014; Spalding et al. 2016). Protection levels vary widely, ranging from full protection, which completely prohibits extractive and often non-extractive use, to various partial protection levels, which prohibit or restrict some uses (such as certain fishing methods), and freely allow others (such as recreational activities) (Rife et al. 2013; Claudet 2018; Grorud-Colvert et al. 2021). When partial protection is implemented it can fail to offer any benefit to biodiversity or biomass in comparison to unprotected areas due to continuation of harmful activities (Turnbull et al. 2018; Zupan et al. 2018; Turnbull et al. 2021). Despite MPAs covering 8.7% of marine space, only 5.7% of the ocean falls within MPAs that have management plans in place or are actively managed and only 2.8% of the ocean is fully or highly protected (allowing no or only light extractive activities) (UNEP-WCMC and IUCN 2024).

1.2.2 Lack of user compliance and support

When MPA usage rules do, in theory, provide adequate protection for biodiversity and fish stocks, lack of compliance from users can mean potential positive results are still not achieved (Spalding et al. 2016). Because measures commonly employed by MPAs are often restrictive in nature, they can have negative impacts on the livelihoods and well-being of MPA users such as fishers and those reliant on the tourism industry, as well as those that have indigenous or cultural connections with marine ecosystems (Stewart & Possingham 2005; Leenhardt et al. 2015; Landuyt et al. 2016). As a result, restricted activities, particularly fishing, can continue to occur illegally within an MPA (Sowman and Sunde 2018), resulting in reduced conservation

success (Advani et al. 2015; Buglass et al. 2018). The CBD 30% area protection target specifies that the expansion of MPAs should remain equitable, and respectful towards the rights of Indigenous Peoples and local communities (UNEP-WCMC and IUCN 2024), and these issues are not only important for ethical approaches to MPA management (Jones 2009), but are fundamental in gaining the support needed to aid MPAs in meeting biological objectives (Edgar et al. 2014; Hoshino et al. 2016; Di Cintio et al. 2023).

1.2.3 Lack of adequate governance

Non-compliance of MPA rules can stem from a variety of factors. A lack of legitimacy of governing institutions, and perceptions of inequity, can mean fishers distrust management decisions and continue prohibited activities (Jones et al. 2013; Rohe et al. 2017). Even when MPA strategies are designed to benefit fishers through improved fish stocks, users can be untrusting or unwilling to face immediate economic loss for unguaranteed long-term gain (Jones 2006). There can be lack of awareness for MPA regulations, or users may be driven to continue with prohibited fishing activities by lack of alternative income options or lack of enforcement of rules (Rohe et al. 2017; Mancha-Cisneros et al. 2018; Iacarella et al. 2021).

Adequate governance is important in addressing these issues. Whilst there is no specific governance approach for MPA success, it is recognised that a sufficient amount of combined governance incentives from a range of economic, legal, participative, knowledge and communication categories, are needed to improve resilience in governance and therefore provide better MPA effectiveness (Jones et al. 2013; Jones et al. 2024). For example, participative incentives can facilitate the inclusion of local users in decision-making (Jones et al. 2013), which can promote equity through social justice and cohesion (Mast et al. 2025) whilst helping encourage local communities to sustainably manage marine resources (Ramirez 2016; Di Franco et al. 2020).

These incentives can create capacity for collaborative learning and promote positive attitudes towards peer enforcement (Singer and Jones 2021), helping mitigate illegal

activity. These collaborations in governance can also provide benefits to MPAs through better diversity of knowledge and increased funding opportunities, through the inclusion of governing organisations such as NGOs (Jones et al. 2013; Ramirez 2016). Economic incentives can support livelihoods through investments in alternative livelihoods such as ecotourism (Spalding et al. 2016; Iacarella et al. 2021), or compensation packages to address lost benefits (Spalding et al. 2016). Legal incentives can provide support through aspects such as legal allocation of responsibilities and property rights (Jones et al. 2013). However, whilst the inclusion of these incentives is considered important in achieving suitable governance for effective MPAs, they are often lacking due to lack of research, ecological and socioeconomic knowledge, funding and political support (Pomeroy et al. 2005).

1.3 Considering locational differences in MPA design

Successful MPA design can be highly specific to its individual objectives, ecosystem types, socioeconomic characteristics, and primary threats (Spalding et al. 2016). Some areas may be under threat from disturbance and damage caused by rapid coastal development (Santos et al. 2015; Nanajkar et al. 2019). Shallow inshore habitats such as seagrass meadows, may be most susceptible to pollution (Grech et al. 2012), whilst others such as biogenic reefs can be more in need of protection from demersal fishing practices (Kaiser et al. 2003). Protected species within an MPA can be under different threats depending on species' mobility, larval dispersal, and fecundity, creating a need for specific protection measures (Edgar et al. 2014; Davies et al. 2018; Conners et al. 2022). Bycatch risks caused by non-target fishing practices can be more important to address when aiming to protect megafauna (Lewison et al. 2014), and various ecological features of an MPA can make successful habitat restoration or aquaculture projects unattainable (Ruff et al. 2019; Jones et al. 2022; Pogoda et al. 2023).

A country's developmental status can also shape the type of MPA management and governance required, due to differing threats and socioeconomic needs. Those in poverty are often more reliant on natural resources, and less able to diversify their

incomes. This can lead to higher rates of non-compliance in the face of fishing restrictions, causing ongoing overexploitation (Brown et al. 2001; Gill et al. 2019; de Oliveira Júnior et al. 2021). Threats in developing areas can also be exacerbated by factors such as inadequate waste management (Jambeck et al. 2015) and enhanced global warming impacts, due to the typical geographical location of less economically developed countries (Nath and Behera 2011).

Corruption issues, social inequalities, and lack of financial resources can make it difficult for adequate MPA protection to occur in poorer communities (Nath and Behera 2011). Governance strategies need to allow communities to escape poverty and high dependency on natural resources (de Oliveira Júnior et al. 2021). Supporting alternative income opportunities for those affected by natural resource restrictions may be required (Silva 2006), as well as increased funding to allow for adequate MPA management in protecting these often highly biodiverse areas (Fisher and Christopher 2007; Jones et al. 2011). Such differences in biological and socioeconomic factors of an MPA need to be considered in MPA management.

1.4 Habitat creation as an alternative MPA management approach

Habitat creation is becoming increasingly used in MPAs as a tool for ecosystem conservation. This study considers this approach as a potential method in reducing socioeconomic losses in MPAs, in efforts to reduce trade-offs and improve effectiveness in meeting objectives. Habitat creation, in the context of this study, is considered as the active restoration of existing habitats or the creation of new habitat, through the planting of coral fragments or seagrass seeds for example (Tan et al. 2020). Creating habitat in these ways can introduce new structure to the environment, which can have positive impact on localised fish abundance and biodiversity (Hutchison et al. 2014; Boakes et al. 2022; Lovelock et al. 2022).

This approach could provide benefit to fishers through an increase in commercially important fish species (Mumby et al. 2004; Hutchison et al. 2014). It can provide jobs and upskilling through restoration work, and economic benefits to local communities

(Vandenberg et al. 2021), as well as intangible benefits such as communities' sense of place, optimism and community resilience (Smith et al. 2025). In some cases, these projects can boost tourism through increased appeal for recreation such as diving. This can provide business opportunities, the potential for marine park user fees, and can reduce the pressure of visitation levels at natural reefs (Claudet and Pelletier 2004; Kirkbride-Smith et al. 2016). Projects such as coral reef restoration programmes can also create restorative ecotourism, where participants pay to take part in restoration activities, which provides project funding and further increases tourism, providing for additional economic opportunity (Hesley et al. 2017).

Habitat creation can also enhance ecosystem services, such as coastal protection (Guannel et al. 2016), increased water quality (de los Santos et al. 2020) and carbon sequestration (Howard et al. 2017). Mangrove and seagrass habitats can support global climate change mitigation by sequestering carbon, making them viable for blue carbon credit initiatives. With rising demand for verified carbon credits and a limited supply, these projects could generate funding while contributing to climate change reduction (Friess et al. 2022).

1.5 Low trophic-level aquaculture as an alternative management approach

Aquaculture of low trophic-level marine species, which in the context of this study will refer to the farming of bivalves and macroalgae, is a concept that can be used for biological and socioeconomic gain in the marine environment, whilst often being compatible with MPA conservation objectives (Suplicy 2020; Mascorda Cabre et al. 2021). Seaweed and bivalve aquaculture can contribute to world food security, with less negative environmental impact than most terrestrial farming practices due to lower energy requirement and zero feed or fertiliser needs (Krause et al. 2022). These farms can provide benefits to coastal communities through the provision of employment opportunities (Larson et al. 2021; Rimmer 2021; Suwendri et al. 2021), economic development (Suplicy 2020), and in some cases, boost tourism through either farm tours or attraction to local aquaculture produce (Caroppo et al. 2012).

Whilst the primary reason for the establishment of aquaculture is to generate product for income, it can create ecological improvements as a secondary benefit. Aquaculture can introduce novel habitat, such as mussel ropes, which provide structure, food and shelter for a number of species (Theuerkauf et al. 2022), which in turn can enhance populations and species richness of ecologically and commercially important organisms (Mascorda Cabre et al. 2021; Corrigan et al. 2024; Mascorda-Cabre et al. 2024a). Mussel and seaweed farms can enhance water quality by filtering excess nutrients (Feng et al. 2023), increase coastal protection (Zhu et al. 2020), and can often offer carbon sequestration, offering potential contribution to net climate change targets (Feng et al. 2023).

Whist some species used in aquaculture, such as tilapia and shrimp, can be referred to as lower-trophic level compared to carnivorous fish such as salmon, these species still require feed inputs, and can be associated with significant environmental impacts, including GHG emissions, habitat degradation, nutrient pollution, biodiversity loss and the spread of pathogens (Krause et al. 2022; Macusi et al. 2022). This study focuses specifically on low-trophic-level aquacultures that do not require feed or fertilisers, and that have potential to create novel habitat, namely the farming of bivalves and macroalgae.

1.6 The scope of this study

The common failure of MPAs to meet objectives due to the ecological and socioeconomic trade-offs often created by activity restriction, indicates a need for these issues to be considered in MPA design. As a proposed solution, this study aims to identify how using habitat creation through *a)* increases of naturally occurring habitat, and *b)* an increases in already established, low trophic-level aquaculture could perform as a management approach in reducing these trade-offs, through potential ecological benefits that could support fish stocks, tourism, and aquaculture jobs. Potential benefits could provide opportunity for less restrictive approaches, more economic opportunity and therefore the potential for reduced trade-offs between conservation and local community.

1.7 Aims and objectives

This study aims to identify how habitat creation compares to restricted fishing approaches in meeting MPA objectives, and to identify the governance incentives which would allow these objectives to be achieved.

The objectives of this study are:

1) To compare the impact of different conservation approaches (habitat creation vs restrictive approaches), on the ecological and socioeconomic aspects of two MPA case studies, through a predictive model.

2) To identify the governance incentives needed to achieve the most effective management approaches considered.

3) To identify how effective management approaches and proposed governance incentives compare between restrictive and restorative conservation approaches, and to identify any common trends or divergent themes.

1.8 Structure of the thesis

This thesis is organised into 5 chapters. The next chapter (chapter 2) provides the research methodology, including a synopsis of the case studies, details of the data collection procedure, proposed scenarios and methods for running the model. Chapter 3 is in two parts. Firstly, the model outputs are presented to identify the management scenarios predicted as most successful. Secondly, an analysis of suitable governance for the most effective scenarios is compared with the existing governance employed at each case study. Chapter 4 interprets the key findings of this study, and outlines the potential benefits and limitations of the proposed scenarios, alongside key differences in results between both case studies.

2. Methodology

2.1 Overview

This study uses complex system modelling to create simultaneous predictions of how various management interventions will impact ecological and socioeconomic aspects of an MPA. Once identified, the necessary governance required for achieving the proposed successful scenarios are evaluated. In this study successful scenarios are determined as those with the most overall positive outcomes for seven key nodes including biodiversity, local jobs and community acceptance. These nodes were chosen as they represent key biological conservation and social MPA objectives. The management approaches and proposed governance for successful execution of these approaches are compared in two ecologically and socioeconomically different MPAs, and comparisons are drawn on how differing MPA characteristics react to MPA management approaches.

2.2 Case studies

This study employs a comparative analysis of two ecologically and socioeconomically distinct MPAs to evaluate how environmental variability, anthropogenic pressures, and societal contexts influence the effectiveness of management interventions. The selected case studies, Lyme Bay MPA in South-West England, UK, and Nusa Penida MPA in Indonesia, offer a contrast between temperate and tropical marine ecosystems, enabling comparisons of ecological responses to protection measures.

The MPAs also face differing anthropogenic stressors, such as variations in fishing practices, recreational use, and coastal development intensity. These factors allow for an examination of how diverse threat profiles influence management outcomes. The socioeconomic contexts of the two sites also displays differences, as Lyme Bay represents a long-established, economically developed fishing community, whereas

Nusa Penida is a less developed area undergoing rapid growth in marine tourism. These distinctions facilitate assessment of how levels of development and cultural heritage affect the implementation, success, and social acceptance of MPA management strategies.

2.2.1 Nusa Penida MPA

Nusa Penida MPA is an approximate 200 km² area, situated south-east of the Indonesian island of Bali, covering the coastal waters of the islands of Nusa Penida, Nusa Lembongan and Nusa Ceningan (Carter et al. 2014). The MPA is situated within the Coral Triangle, which is an area considered extremely rich in biodiversity, representing 76% of the worlds coral reef species (Veron et al. 2009) and 37% of the worlds reef fish species (Allen 2008). The MPA was established in 2010, and after community consultation, was fully appointed in 2014 (Carter et al. 2014), now falling under the authority and management of the Bali Province Government (Coral Triangle Centre [CTC] 2019). The overall objective of the MPA is to:

> "protect the marine biodiversity of the area, support sustainable fisheries, marine tourism, and the welfare of local communities" (Carter et al. 2014).

Specific conservation objectives include the achievement of healthy habitats that provide food sources and tourism sources, healthy and unique marine species for tourism attraction, and the development of environmentally friendly and sustainable fisheries. Operational objectives include long, medium, and short-term management plans, collaborative management amongst MPA users, promotion of sustainable tourism that benefits local communities, clear and strong framework for management with sufficient capacity, and surveillance and sustainable financing (Yunitawati and Clifton 2021).

The MPA consists of diverse ecosystems and marine megafauna, which attract tourism for diving and snorkelling. Aggregating sunfish (*Mola mola*) and manta rays (*Manta spp.*) are common in the area, which act as primary tourist attractions, and therefore hold economic importance (Yunitawaiti and Clifton 2021). However, increasing tourism pressure creates the challenge of damage to coral reefs and

plastic pollution (CTC 2019). Seaweed farms operate within the MPA, which were rapidly developed between 1990-2010 (Carter et al. 2014, Suwendri et al. 2021). The farming created income opportunities to local communities (Suwendri et al. 2021), alongside incomes generated from fisheries and tourism (Carter et al. 2014). The MPA is divided into zones, made up of NTZs, different usage restrictions, and a seaweed cultivation zone (Yunitawati and Clifton 2021). Community groups have established coral and mangrove restoration projects, in efforts to improve damaged ecosystems (CTC 2019). Despite some positive outcomes reported for fish biomass, there has been a lack of consistent monitoring (Sebastion et al. 2024) and under review, the MPA has been summarised as “only partially addressing impacts” (Yunitawati and Clifton 2021; Jones et al. 2024).

2.2.2 Lyme Bay MPA

Lyme Bay MPA is situated in the English Channel, South-West of England, and is considered a biodiversity hotspot. Hosting diverse and uncommon habitats such as stony reef and sea caves, Lyme Bay supports high species richness of hydroids, anemones, sea squirts, sponges, corals, kelp, and blue mussel communities (Natural England 2015). The site is also home to commercially important scallops, crabs, lobster and whelks (Mangi et al. 2011). Fishing in the area is of economic importance, as well as recreational activities such as angling and diving (Singer and Jones 2021). The MPA is made up of two overlapping designations (Renn et al. 2024), and its overall objectives are to:

> “forge links between fishermen, conservationists, regulators and scientists in order to maintain a healthy, productive and sustainable Marine Reserve, with the aim to protect biodiversity, sustainably manage fish and shellfish stocks, and create long term benefits for local communities” (Lyme Bay Fisheries and Conservation Reserve [LBFCR] 2025a).

Initial voluntary trawling closures were established in 2001, due to concerns on reef damage caused by bottom-towed fishing/shellfish dredging. In 2008, the area was extended and legally enforced, due to the limited effectiveness of the voluntary bans,

creating a continuous 206 km^2 trawling ban and a de facto MPA, through The Lyme Bay Designated Area (Fishing Restrictions) Order (2008). This statutory instrument (SI) caused conflict with local fishers, and a committee was later formed to help balance the needs of the fishing community with habitat protection goals (Renn et al. 2024). This group went on to set new voluntary codes of conduct to limit pot and net fishing and promote best practice for recreational angling, to manage fishing practices within sustainable limits (LBFCR 2021; Renn et al. 2024; LBFCR 2025b).

In 2012, an overlapping 270 km^2 Special Area of Conservation (SAC) was established to further protect Annex 1 habitats within the SI, as well as some found outside the boundaries of the SI in the Lyme Bay area (Singer and Jones 2021). These habitats include reefs and sea caves, under the European Union Habitats Directive (92/43/EEC arts 6 and 17). The SAC imposes a legal obligation to maintain or restore the site's integrity and ensure it contributes to the Favourable Conservation Status of its qualifying features. This involves preserving or restoring the extent, distribution, structure, and function of natural habitats while supporting the ecological processes they depend on (Natural England 2018). To protect these habitats, the SAC restricts the use of demersal towed gear over Annex I reef areas (Natural England 2015). The SAC still permits bottom trawling in the small areas of the SAC that are not Annex 1 protected habitats (and that are also not overlapped by the SI), but only for those with a working satellite or smart phone inshore Vessel Monitoring System (iVMS), through a permitting byelaw (Singer and Jones 2021). Similarly to the SI, static gear fishing and scallop diving are permitted across the SAC (Renn et al. 2024).

In 2013, an offshore mussel farm was established, with two sites situated outside the boundaries of the MPA, and one within it (Stamp et al. 2024). The mussel farm has had reports of ecological success (Stamp et al. 2024), and mixed levels of acceptance from local fishers (Bridger et al. 2022). Whilst the MPA has shown increased species richness and abundance (Sheehan et al. 2013), under review it was found that "some impacts within the MPA are still left unaddressed" (Jones et al. 2024).

2.3 Bayesian belief network models (BBNs)

Models built for each case study were based on a modified Bayesian belief network (BBN) model, as per procedures described in Dominguez Almela et al. (2024). The use of BBNs for networks of complex systems, such as the interlinked components of MPAs, enables predictive outcomes of applied interventions to be produced for entire systems. BBNs are able to generate predictions with scarce data from various sources, can incorporate multiple variables, and can allow for expert knowledge where data is lacking (Henriksen and Barlebo 2008; Landuyt et al. 2013; Stafford et al. 2015). Through the use of these models, the effects of each proposed management approach can be applied to many key aspects of both case studies, and the indirect effects to other components are able to propagate through the system. For example, the effects of increased tourism could damage habitats, which could impact biodiversity and fish stocks, negatively impacting fishing and potentially feeding back to negatively affect tourism.

Nodes

Ecological and socioeconomic components of each MPA were included in each model, in addition to human activities that take place in these MPAs. Each component is classified as a ‘node’ within the model. Nodes were chosen by considering the MPAs objectives (such as the protection of certain species or habitats), species and industries important to the economy, important social wellbeing aspects, and less obvious components that have important direct links between the chosen nodes. Definitions for each node are defined in Table 1.

Table 1. Node titles and definitions, and whether they feature in Nusa Penida and Lyme Bay BBN models

Node Category	Node	Definition	Nusa Penida	Lyme Bay
Biological	Seagrass	The quantity or condition of seagrass habitats within the MPA	Y	
	Mangroves	The quantity or condition of mangrove habitats within the MPA	Y	
	Coral reef	The quantity or condition of coral reef habitats within the MPA	Y	
	Sea caves	The quantity or condition of the sessile/structure forming species within sea cave habitats within the MPA		Y
	Rocky reef	The quantity or condition of the sessile/structure forming species within rocky reef habitats within the MPA		Y
	Stony reef	The quantity or condition of the sessile/structure forming species within stony reef habitats within the MPA		Y
	Zooplankton	The quantity or condition of zooplankton organisms within the MPA	Y	
	Mussels	The quantity or condition of wild or farmed mussels within the MPA		Y
	Invertebrates	The quantity or condition of invertebrate organisms (excluding zooplankton and mussels) within the MPA	Y	Y
	Megafauna	The quantity or condition of megafauna organisms within the MPA, including dolphins, seals, whales, turtles, and sharks		Y
	Fish	The quantity or condition of fish organisms within the MPA	Y	Y

	Manta rays	The quantity or condition manta rays (*Mobula spp.*) within the MPA	Y	
	Sunfish	The quantity or condition of ocean sunfish (*Mola mola*) within the MPA	Y	
	Pink sea fans	The quantity or condition of pink sea fans (*Eunicella verrucosa*) within the MPA		Y
	Sunset cup coral	The quantity or condition of sunset cup coral (*Leptopsammia pruvoti*) within the MPA		Y
	Water quality	The degree to which the water within the MPA is suitable for healthy ecosystems and free from chemical and physical pollutants	Y	Y
	Biodiversity	Overall species richness of all flora and fauna species within the MPA	Y	Y
Human Activity	Bottom towed fishing	Fishing methods that involve trawling fishing gear across the seabed		Y
	Pelagic non-selective fishing	Pelagic fishing methods that use non-selective fishing gear and catch many types of marine species. For example, purse seine fishing	Y	Y
	Selective fishing	Fishing methods that capture target species and avoid non-target species. For example, pole and line fishing, potting and scallop diving	Y	Y
	Boat use	The quantity of motorised boats used in the MPA	Y	Y
	Anchoring	The quantity of boat anchoring occurring in the MPA	Y	Y
	Disturbance	Quantity of noise, light, or movement, within the MPA, caused by human activity. Boat engines, movement, trampling etc	Y	Y
	Recreation	Quantity of recreational activities occurring in the MPA, excluding fishing. Diving, snorkelling, jet skiing, surfing, sailing, kayaking, swimming etc	Y	Y

	Tourism	Quantity of people visiting the MPA from outside the area for leisure	Y	Y
	Seaweed farming	Quantity of seaweed farming taking place within the MPA	Y	
	Mussel farming	Quantity of mussel farming taking place within the MPA		Y
	Coastal development	Construction of new coastline infrastructure within, or surrounding, the MPA. Buildings, ports, pontoons, roads etc	Y	
	Coastal protection	Level of protection against wave velocity, erosion, and flooding	Y	
	Fishing employment	Quantity of local jobs directly created by the fishing industry, including skippers, fish cutters, fishmongers, fishers, deckhands, boat riggers etc.	Y	Y
Socioeconomic	Tourism employment	Quantity of local jobs directly linked to tourism, including hospitality, retail, and recreational services.	Y	Y
	Aquaculture employment	Quantity of local jobs directly linked to aquaculture, including the cultivation or harvest of seaweed or mussels.	Y	Y
	Cultural heritage	The preservation of societal assets, inherited from past generations, specific to the area surrounding the MPA. Activities, job roles, monuments, ceremonies etc.	Y	Y
	Community Acceptance	The willingness of the overall local community to accept management interventions within the MPA.	Y	Y

Edges

The direct cause and effect interactions between each node are classified as edges. Integer values between -4 and 4, were assigned to each edge, depending on how much one node would respond if another node changed. A value of 1 or -1 indicates a weak cause and effect relationship between nodes, and a value of 4 or -4 indicates a strong relationship. Positive values were used when an increase in one node

directly causes an increase in another. Negative values were used when an increase in one node directly causes a decrease in another. For example, an increase in a ‘fishing’ node would cause a direct decrease to a ‘fish’ node, and therefore would be scored a negative value.

Only direct relationships between nodes were assigned a score, as indirect relationships are determined within the model’s process. Values were determined through reviews of existing literature, reports, websites, or through expert opinion. If an edge score was intuitive, or if the author was confident in valuing the edge using expert opinion, then no research was required. When research was required, a literature search was conducted. The approach prioritised finding the most recent research for the specific case studies, and where this was not available, the search was broadened to focus on specific nodes instead. For example, a search might begin with “the impact of disturbance on manta rays in Nusa Penida” and if no results were found, the specific location would be removed to find more general but relevant research. In the absence of relevant scientific literature, a general search for reports and websites was conducted. This method aligns with the ability to use data from multiple resources to build a BBN. A scoring criteria from Dominguez Almela et al. (2024) (see figure 1), was used to enable consistent scoring.

Once each edge was assigned a score, a second expert opinion was provided, so any discrepancies in scoring could be investigated. If an assigned score differed between both individuals’ opinions by more than 1, the edge was reevaluated. This was through further research, or correction of any errors after discussion. For example, discrepancies between the scoring of coral reef and fish were found, so further literature review was conducted to better understand the relationship.

Input value	Edge values	Prior values
4 (or -4)	Strong relationship between parent and child node, creating a clear and noticeable cause and effect relationship. Full (> 95%) agreement between sources for the relationship	Full or large magnitude implementation of a change (i.e. doubling a large population size, increasing costs by 70–100%). It would be difficult to implement the change in greater detail
3 (or -3)	Strong relationship between parent and child node, creating a clear and noticeable cause and effect relationship. Good agreement between sources for the relationship (>75% of data agree) OR Moderate relationship between parent and child nodes. Difference is detectable but may not be obvious. Full agreement between sources for the relationship	Moderate to large scale implementation of a change–i.e. removing 50% of a moderately abundant population
2 (or -2)	Moderate relationship between parent and child nodes. Difference is detectable but may not be obvious. Good agreement between sources for the relationship (>75% of data agree) OR Weak relationship between parent and child nodes. Difference is apparent in studies but might not always be significant (i.e. due to low sample size). Full (> 95%) agreement between sources for the relationship	Small to moderate change. e.g. deer culling to remove 10% of deer
1 (or -1)	Weak relationship between parent and child nodes. Difference is apparent in studies but might not always be significant (i.e. due to low sample size). Good agreement between sources for the relationship (>75% of data agree)	Smaller than above
0	No relationship, or large disagreement between sources	No direct change

Figure 1. Scoring criteria for BBN nodes and priors taken from Dominguez Almela et al. (2024)

Modelling

Models were built using the BBNet package on R version 4.3.2 (R Core Team 2023). Once edge values were assigned, a sensitivity analysis was conducted. This adjusted the edge strengths of the model randomly over 10,000 interactions and identified those which had the most influence on the final results and therefore had the highest need for accurate scoring (see sensitivity analysis procedure in Dominguez Almela et al. [2024] for full details). The most sensitive 10% of edges were re-evaluated to ensure confident scoring. If edges were self-evident, no further research was required, and scores were kept the same. For edges that weren't considered self-evident, further research was conducted before confirming a final value. For example, the edge value for invertebrates' impact on sunfish was one of

those re-evaluated. After further literature review, it was considered that although sunfish primarily and most reportedly eat zooplankton (a separate node), it was evident that sunfish diet also quite often consists of crustaceans, brittle stars, molluscs, hydroids (Pope et al. 2010). Whilst no research was available to confirm whether reduction in invertebrates (excluding zooplankton) would cause sunfish decline, it was recognised that a moderate relationship existed through the food chain, and the score was changed from 1 (weak relationship) to 2 (moderate), to represent this. 20 edges were re-examined per case study and overall, three edge scores were adjusted by one number, and one was adjusted by two numbers (table 3). The majority of scores were considered correct, indicating good accuracy of the model.

Table 2. Number of edges re-examined and rescored following sensitivity analysis

Case study	Edges re-examined	Kept at current score	Changed by 1 number	Changed by 2 numbers	Changed by more than 2 numbers
Lyme Bay	20	18	0	1	0
Nusa Penida	20	17	3	0	0

Scenarios

To enable the BBN to generate predictive outputs on the impact of new management approaches for each node, a series of scenarios were developed and applied to the model. Scenarios were designed to replicate a range of potential MPA management approaches (see table 3). These consisted of:

a) Two habitat creation scenarios which imply either an increase in aquaculture operations within the MPA as a means of creating novel habitat, or an improvement to the key habitats within the MPA which could be achieved through active restoration.

b) Two restrictive scenarios representing conventional MPA management approaches. One scenario replicates a complete NTZ, where all fishing activities stop within the MPA, while the other simulates a Partially Protected Area (PPA), where fishing activity is reduced but not entirely prohibited.

c) Two scenarios, which increase alternative livelihood opportunities alongside PPA rules as a means of reducing socioeconomic loss caused by loss of fishing opportunities. This is represented through increases in aquaculture or tourism within the MPA, and a reduction in fishing activity.

The effects of each management scenario on human activities were considered, and prior values were given to each directly affected node using the same scoring criteria used for the BBN nodes (see table 4 & 5). For example, fishing restrictions would result in a prior negative score for fishing nodes for that particular scenario, as fishing activity would reduce. These priors were separately applied to the model for each case study to identify their impacts.

Table 3. management scenarios applied to Nusa Penida and Lyme Bay BBN models

Scenario	Management Approach
Scenario 1	Active restoration: The improvement of key habitats within the MPA due to the introduction of artificial structures and/or the planting of flora such as seagrass, mangroves and corals.
Scenario 2	Aquaculture increase: An increase in aquaculture operations due to expansion of seaweed or mussel farms, provided by government investment, or permits to expand.
Scenario 3	No-Take Zone (NTZ): A complete ban of all fishing within the MPA, including trawling, pelagic and selective fishing.
Scenario 4	Partially Protected Area (PPA): Reductions in non-selective fishing, within the MPA, due to rules such as fishing gear restrictions.
Scenario 5	PPA & increased tourism: Reductions in non-selective fishing, within the MPA, due to rules such as fishing gear restrictions. An increase in tourism intensity potentially achieved through promotion/marketing initiatives.
Scenario 6	PPA & increased aquaculture: Reductions in non-selective fishing, within the MPA, due to rules such as fishing gear restrictions. An increase in aquaculture operations due to expansion of seaweed or mussel farms, provided by government investment, or permits to expand.

Table 4. Prior scores given to each node for each management scenario applied to Nusa Penida model

Node	Scenario 1. Active restoration	Scenario 2. Aquaculture increase	Scenario 3. NTZ	Scenario 4. PPA	Scenario 5. PPA & increased tourism	Scenario 6. PPA & increased aquaculture
Seagrass	2					
Mangroves	2					
Coral reef	2					
Pelagic non-selective fishing			-4	-2	-2	-2
Selective fishing			-4			
Tourism					2	
Seaweed farming		3				2

Table 5. Prior scores given to each node for each management scenario applied to Lyme Bay model

Node	Scenario 1. Active restoration	Scenario 2. Aquaculture increase	Scenario 3. NTZ	Scenario 4. PPA	Scenario 5. PPA & increased tourism	Scenario 6. PPA & increased aquaculture
Sea caves	2					
Rocky reef	2					
Stony reef	2					
Mussels		3				2
Bottom towed fishing			-4	-2	-2	-2
Pelagic non-selective fishing			-4	-2	-2	-2
Selective fishing			-4			
Tourism					2	

2.4 Governance incentives

Once the most successful management scenario for both reference sites was established, a series of governance incentives (taken from Jones et al. 2024) were evaluated against the proposed scenario to establish which incentives, and how many, would likely be needed to achieve success and how these may differ from current approaches.

Table 6. Governance incentive categories and definitions taken from Jones et al. (2024)

Incentive Category	**Definition (number of Incentives in category)**
Economic	Using economic and property rights approaches to promote the fulfilment of MPA objectives (10).
Communication	Promoting awareness of the conservation features of the MPA, the related objectives for conserving them and the approaches for achieving these objectives, and promoting support for related measures (3)
Knowledge	Respecting and promoting the use of different sources of knowledge (local-traditional and expert-scientific) to better inform MPA decisions (3)
Legal	Establishment and enforcement of relevant laws, regulations etc. as a source of ‘state steer’ to promote compliance with decisions and thereby the achievement of MPA obligations (10)
Participative	Providing for users, communities and other interest groups to participate in and influence MPA decision-making that may potentially affect them, in order to promote their ‘ownership’ of the MPA and thereby their potential to cooperate in the implementation of decisions (10)

Table 7. Governance incentives definitions taken from Jones et al. (2024)

Incentive Category	Incentive	Definition
Economic (10)	i1. Payments for ecosystem services (PESs)	Direct payments for ecosystems services* provided by the MPA through formal markets with open trading between buyers and sells, e.g., Blue Carbon payments as the marine equivalent of REDD+ payments
	i2. Assigning property rights	Assigning or reinforcing property rights for certain areas and resources to appropriate groups of people to promote ownership, stewardship, rational self-interest in sustainable exploitation, etc.
	i3. Reducing the leakage of benefits	Measures to reduce the 'leakage' of the economic benefits of the MPA away from local people, including measures to promote the fair distribution of such benefits amongst local people, e.g., restricting incoming fishers, promoting ecotourism that maximises the income received by local people through locally operated businesses, home-stay accommodation, employing locals in tourist facilities, commercial operations run by the MPA authority itself, etc.
	i4. Promoting profitable and sustainable fisheries and tourism	Avoiding 'boom-bust' development trajectories, e.g. promoting sustainable fisheries by providing a refuge for marine organisms in no-take zones in order to safeguard and enhance harvests in adjacent fishing grounds through spill-over/export, insurance against uncertainty, along with the promotion of conventional fisheries management approaches; promoting the development of tourism in a sustainable 'eco' manner that does not lead to the degradation of the environment to which tourists are attracted.
	i5. Promoting green marketing	Promoting the 'green marketing' of appropriate tourism, fisheries, *etc.* within the MPA to increase profits and income, including market premiums for well conserved fishery resources and tourist/diver user fees for access to the MPA or particular zones.
	i6. Promoting diversified and supplementary livelihoods	Promoting the diversification of livelihoods and supplementary options to gain more income from such livelihoods, including alternative economic development opportunities, which are compatible with the achievement of the MPA's biodiversity conservation objectives, whilst generating sustainable income for local people.
	i7. Providing compensation	Providing fair economic compensation for those users who carry costs as a result of restrictions on their activities that cannot reasonably be offset through alternative compatible opportunities, *e.g.* fisheries buy-outs, decommissioning schemes.
	i8. Investing MPA income/funding in	Investing some of the income from or funding for the MPA to develop local facilities (schools, medical care, family planning, *etc.*) and

	facilities for local communities:	infrastructure (roads and other transport links, electricity, water, *etc.*).
	i9. Provision of state funding	Ensuring that a sufficient degree of state funding is available, alongside other funding (see below), to support the governance of the MPA, particularly to enable a longer-term strategic approach, and in relation to enforcement capacity, whilst ensuring that such funding does not allow the state to 'capture' MPA governance by undermining the role of participation incentives.
	i10. Provision of NGO, private sector and user fee funding	Seeking corporate, NGO and private funding through endowments, donations, debt conversions, trust funds, *etc*. to support the governance of the MPA, whilst ensuring that such funders cannot 'capture' MPA governance through an inappropriate degree and type of influence, and that the MPA becomes financially sustainable through a diversity of income sources so that it is not critically vulnerable to the withdrawal of private sector funding. Funding can also be raised through 'user fees' on individual visitors and/or through 'tourism tax' on businesses using the protected area as location for hotels of for diving, recreational fishing, etc., potentially also serving to manage user numbers.
Communication (3)	i11 Raising awareness	Using social and local media, TV & radio and other approaches to overcome 'out of sight, out of mind' barriers by raising the awareness of users, local people, relevant authority officers, politicians, etc. about the aesthetic values, ecological importance and vulnerability of marine biodiversity.
	i12. Promoting recognition of benefits	Promoting recognition of the potential resource benefits of the conserved areas in terms of spillover/export benefits for wider fisheries, insurance/resilience, *etc.*, whilst being realistic about such potential benefits and not 'over-selling' them.
	i13. Promoting recognition of regulations and restrictions	Promoting recognition of and respect for the MPA's regulations and restrictions, including the boundaries.
Knowledge (3)	i14. Promoting collective learning:	Promoting mutual respect amongst local people and scientists for the validity of each other's knowledge and promoting collective learning and the integration of different knowledges through partnership research, research/advisory groups, participative GIS, participative workshops, *etc.*
	i15. Agreeing approaches for addressing uncertainty	Explicitly recognising the challenges raised by scientific uncertainty and agreeing approaches to address such challenges, *e.g.,* ground rules for the interpretation and application of the precautionary principle, decision-making under uncertainty, and adaptation in the light of emerging knowledge.

	i16. Independent advice and arbitration	Seeking independent advice and/or arbitration from recognised and respected experts in the face of conflicting information and/or uncertainty.
Legal (10)	i17. Hierarchical obligations	International-regional-national-local legal obligations that require effective MPA conservation, including the potential for top-down interventions.
	i18. Capacity for enforcement	Following the principles of decentralisation, ensure that sufficient government capacity, political will, surveillance technologies and financial resources are available at all relevant regulatory levels to ensure the equitable and effective enforcement of all restrictions on all local and incoming users, including related pressures from fisheries and tourism market forces.
	i19. Penalties for deterrence	Effective judicial system for proportionately penalising illegal resource users in a way that provides an appropriate level of deterrence and helps address conflicts that would otherwise undermine marine conservation objectives.
	i20. Protection from incoming users	Providing for a degree of legal protection from incoming users, particularly non-local fishers, as well as tourism operators, recognising that exploitation by incoming users often poses a major threat to local biodiversity and resources.
	i21. Attaching conditions to use, property rights, decentralisation, etc	Agreeing performance standards, conditions, criteria and requirements related to the MPA's conservation objectives and attaching them to user and property rights, licences, decentralisation agreements, participatory governance structures, *etc.*
	i22. Cross-jurisdictional coordination	Legal or other official basis for coordination between different authorities, and between conservation and other government agencies/law enforcement units, to address cross-jurisdictional and cross-sectoral conflicts in order to support the achievement of MPA objectives, e.g. watershed management by pollution authority, fish stock management by the fisheries authority, forestry management by the forestry authority, recognising that the environment authority with responsibility for MPAs often does not have direct jurisdiction over other sectoral activities that can impact the MPA's conservation features.
	i23. Clear and consistent legal definitions	Clarity and consistency in legally defining the objectives of MPAs, general and zonal use regulations, jurisdictional boundaries, roles and responsibilities of different authorities, decentralisation arrangements, etc.
	i24. Clarity concerning jurisdictional limitations	Promoting clarity and openness concerning the jurisdictional limitations of the MPA legislation, *i.e.,* recognising which driving forces, activities and impacts cannot be directly addressed by the

		MPA legislative framework and exploring alternative means of addressing such factors.
	i25. Legal adjudication platforms	Employing legal, customary law and other formal and widely respected decision-making platforms to address and regulate conflicts, when required, especially to promote the legitimacy, accountability and fairness of legal processes and decisions.
	i26. Transparency, accountability, and fairness	Establishing legal provisions to ensure transparency, accountability, legitimacy and fairness in MPA management processes, *e.g.,* statutory requirements for public access to information, appeals, public hearings, judicial reviews, *etc.*
Participative (10)	i27. Rules for participation	Clear rules on participation from different groups and the representation of all user groups in participation processes in a manner that minimises the undue influence of particular vested interests and promotes the inclusivity and legitimacy of the participatory processes.
	i28. Establishing collaborative platforms	Developing participative governance structures and processes that support collaborative planning and decision-making, *e.g.,* user committees, participative planning workshops, *etc.*, including training to support such approaches.
	i29. Neutral facilitation	Bringing in neutral facilitators to support governance processes and negotiations, particularly in relation to collaborative platforms, as deliberations are more likely to progress and agreements to be negotiated if such neutral facilitation is provided for.
	i30. Independent arbitration panels	Employing neutral and locally respected panels of actors who do not have direct stakes in the MPA, and decisions related to it but have relevant sectoral expertise to arbitrate on issues, provide advice and recommend decisions.
	i30. Independent arbitration panels	Employing neutral and locally respected panels of actors who do not have direct stakes in the MPA, and decisions related to it but have relevant sectoral expertise to arbitrate on issues, provide advice and recommend decisions.
	i31. Decentralising responsibilities	Decentralising some roles, responsibilities and decision-making authorities to local organisations and people through a clear management structure, whilst maintaining an appropriate degree of the authority of and accountability to higher level state organisations, in order to ensure that strategic conservation objectives are effectively met, along with related equity objectives, being open and realistic about the degree of autonomy and influence that local organisations and people can expect.
	i32. Peer enforcement	Providing for participative enforcement, *e.g.* peer enforcement, community rangers/wardens, and promoting the potential for

	cooperation and peer enforcement through the development of a sense of ownership of the MPA and respect for related decisions.
i33. Building trust and the capacity for cooperation	Building trust amongst individuals through transparency, face-to-face discussions, equity promotion, *etc.*, promoting cooperation and confidence that this will be reciprocated amongst MPA users.
i34 Building linkages between relevant authorities and user representatives	Developing and strengthening linkages amongst relevant government authorities and key user representatives, including mutual trust, in order to promote the fulfilment of legal conservation objectives and build resilient governance structures.
i35.	Promoting consistency with and respect for local traditions, customs, norms and practices, in so far as they are compatible with and contribute towards the fulfilment of legal conservation objectives, including scope for flexibility, negotiations and compromises.
i36. Potential to influence higher institutional levels	Promoting recognition & realisation of the potential for the participative governance of a given MPA to influence the higher/wider policy framework through institutional learning, *i.e.* that local people can have an influence on higher level institutions and related decisions, as well as being influenced by them, in a coevolutionary manner.

3. Results

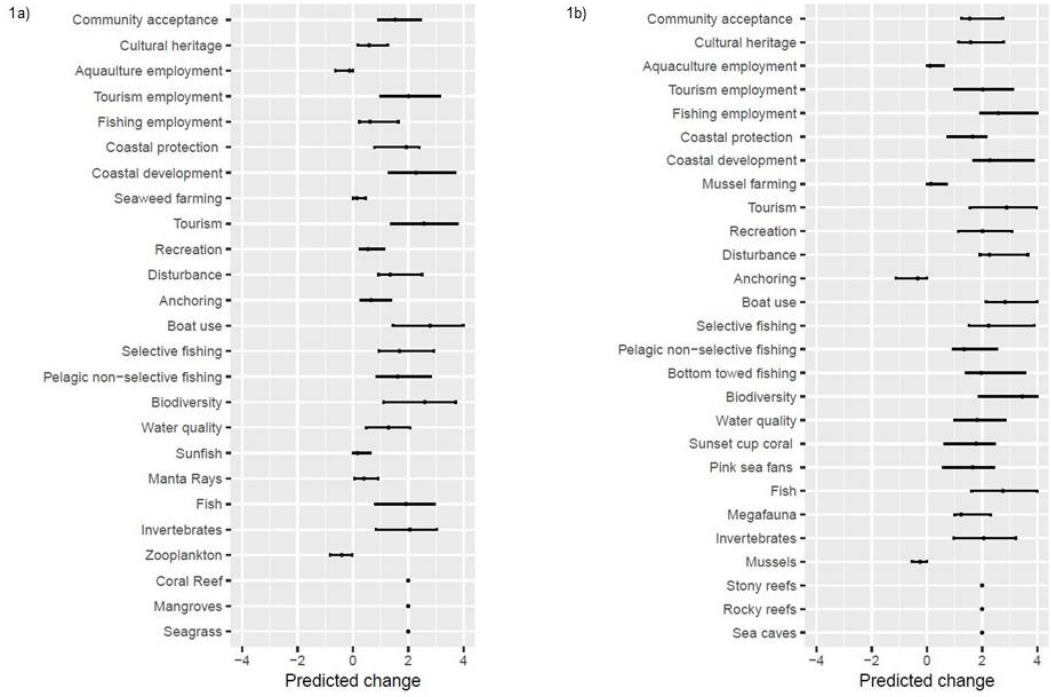
3.1 BBN results

The data obtained from BBN models is presented, showing the predictive outputs for both case studies, for all six management scenarios. Firstly, predictive outputs for all nodes are shown. Secondly, the output results for seven key nodes are presented.

3.1.1 Habitat creation scenarios

Scenario 1. Active restoration

This scenario resulted in a predicted increase in all nodes at Nusa Penida, except for aquaculture employment and zooplankton nodes (see Fig. 1a). All nodes at Lyme Bay increased, except for anchoring and mussels (see Fig. 1b). For the seven key nodes, increases in tourism employment and community acceptance were roughly equal across both case studies, but increases in other key nodes were larger for Lyme Bay (see Fig. 1c).



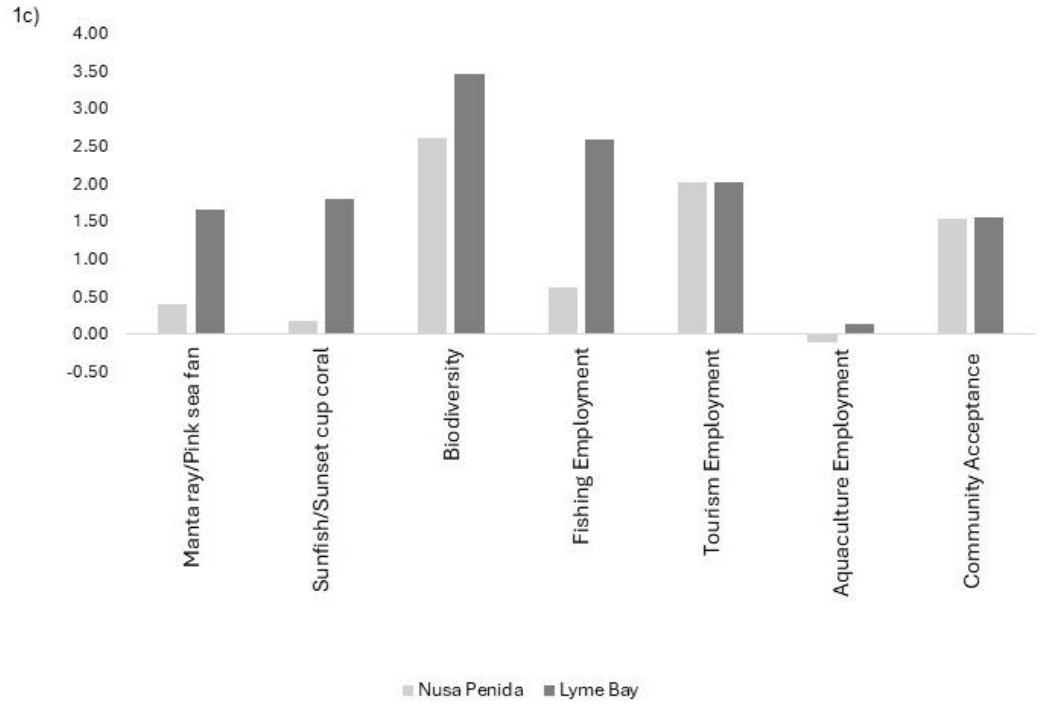
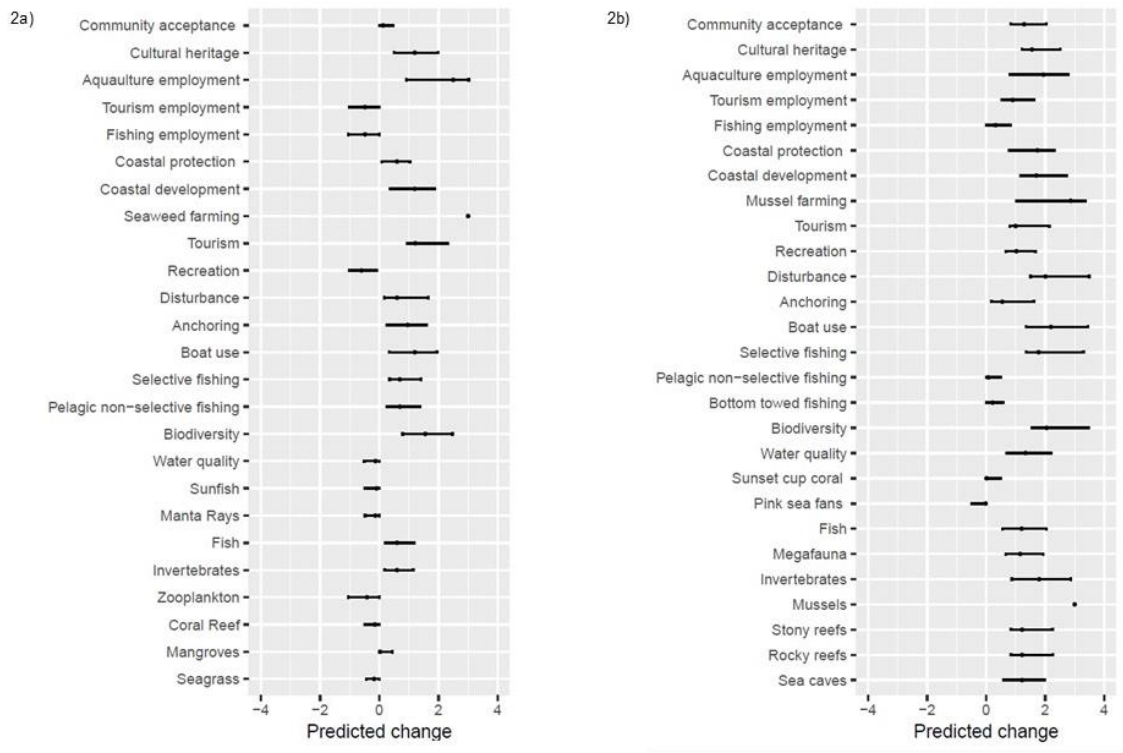


Figure 2. Outputs of BBN prediction for scenario 1 (improvements to 3 key habitats within the MPA). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes between sites.

Scenario 2. Aquaculture increases

This scenario resulted in decreases in tourism employment, fishing employment, recreation, water quality, sunfish, manta rays, fish, zooplankton, coral reef and seagrass nodes in Nusa Penida, whilst all other nodes increased (see Fig. 2a). For Lyme Bay, all nodes increased, except for a decline in pink sea fans and no change to sunset cup coral nodes (see Fig. 2b). For the seven key nodes, community acceptance and biodiversity increased more at Lyme Bay and aquaculture employment increased more at Nusa Penida. Fishing and tourism employment increased in Lyme Bay whilst declining in Nusa Penida, and manta ray and sunfish in Nusa Penida were predicted to decline more than pink sea fans and sunset cup corals in Lyme Bay (see Fig. 2c)



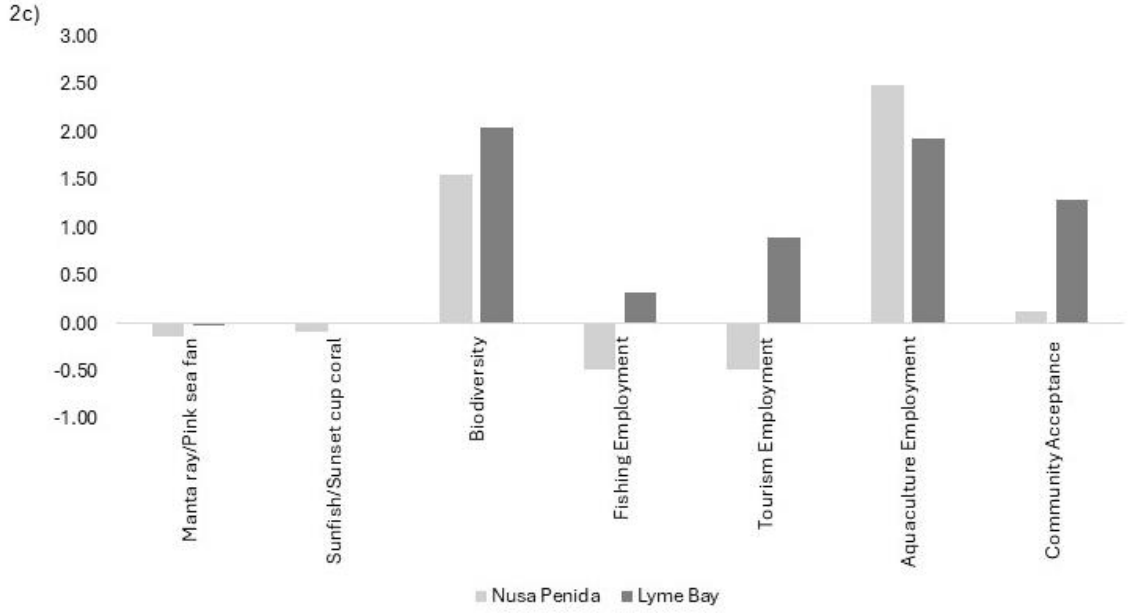
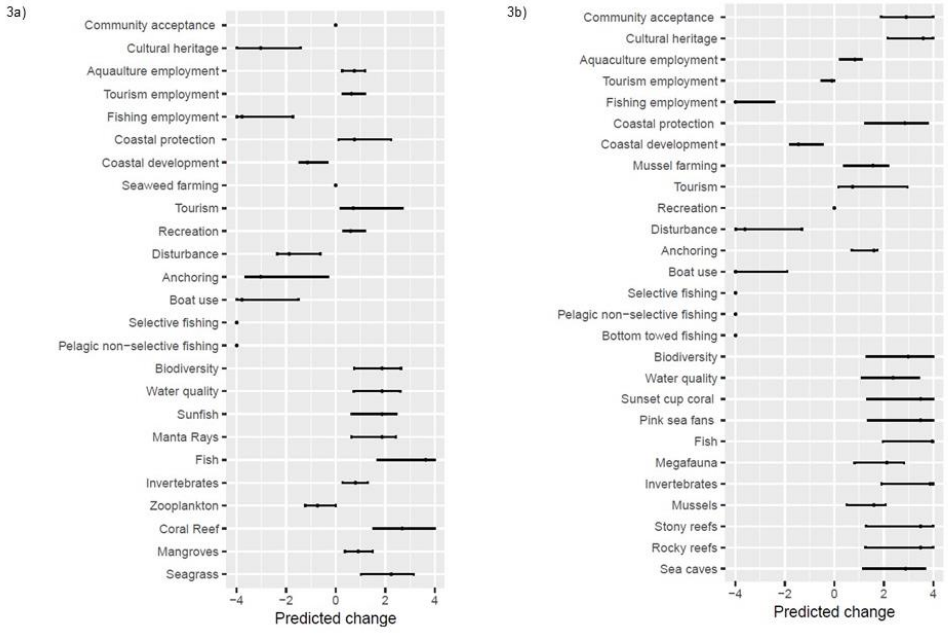


Figure 3. Outputs of BBN prediction for scenario 2 (increased seaweed farming in Nusa Penida MPA and increased mussel farming in Lyme Bay MPA). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes between sites.

3.1.2 Restricted fishing scenarios

Scenario 3. No-Take Zone

This scenario had no impact on community acceptance and seaweed farming nodes in Nusa Penida whilst decreases were seen in cultural heritage, fishing employment, coastal development, disturbance, anchoring, boat use and zooplankton. Increases were predicted for all other nodes (see Fig. 3a). For Lyme Bay, decreases were shown for tourism employment, fishing employment, coastal development, disturbance and boat use, whilst all other nodes increased, and recreation remained the same (see Fig. 3b). For the seven key nodes, tourism employment decreased in Lyme Bay whilst increasing in Nusa Penida, and fishing employment decreased in both scenarios, with a larger decrease seen in Lyme Bay. Community acceptance was predicted to increase for Lyme Bay but was unaffected in Nusa Penida. Remaining key nodes were predicted to increase at both MPAs but more of an increase was seen in Lyme Bay (see Fig. 3c).



3c)

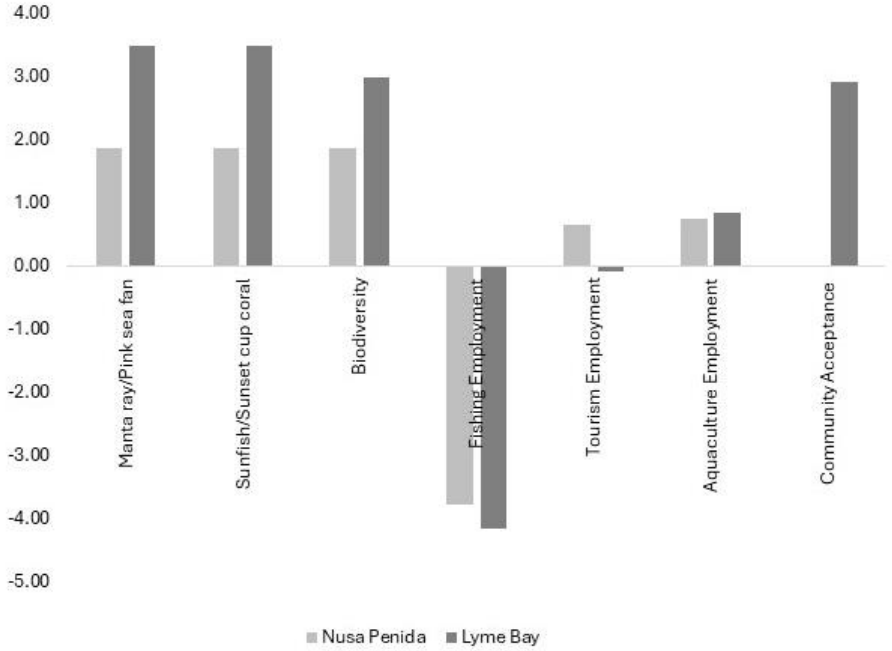
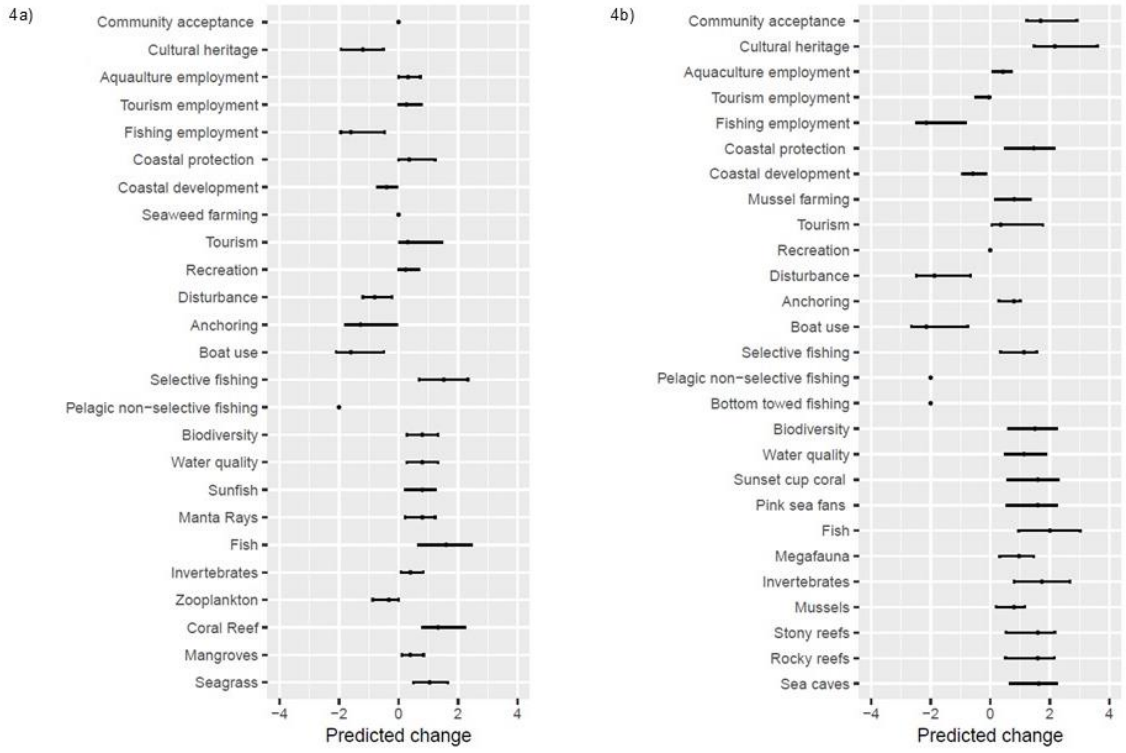


Figure 4. Outputs of BBN prediction for scenario 3 (complete fishing bans within the MPAs). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes between sites.

Scenario 4. Partially Protected Area

This scenario had no impact on community acceptance and seaweed farming nodes in Nusa Penida, and resulted in a decrease in cultural heritage, fishing employment, coastal development, disturbance, anchoring, boat use, pelagic non-selective fishing and zooplankton. All other nodes increased (see Fig. 4a). For Lyme Bay, recreation was not impacted, and nodes for tourism employment, coastal development, disturbance, boat use, pelagic non-selective fishing and bottom towed fishing decreased. All other nodes increased (see Fig. 4b). For the seven key nodes, tourism employment decreased in Lyme Bay whilst increasing in Nusa Penida, and fishing employment decreased in both case studies, with a larger decrease in Lyme Bay. Community acceptance was predicted to increase for Lyme Bay but was unaffected in Nusa Penida. Remaining key nodes were predicted to increase at both MPAs but more of an increase was seen in Lyme Bay (see Fig. 4c).



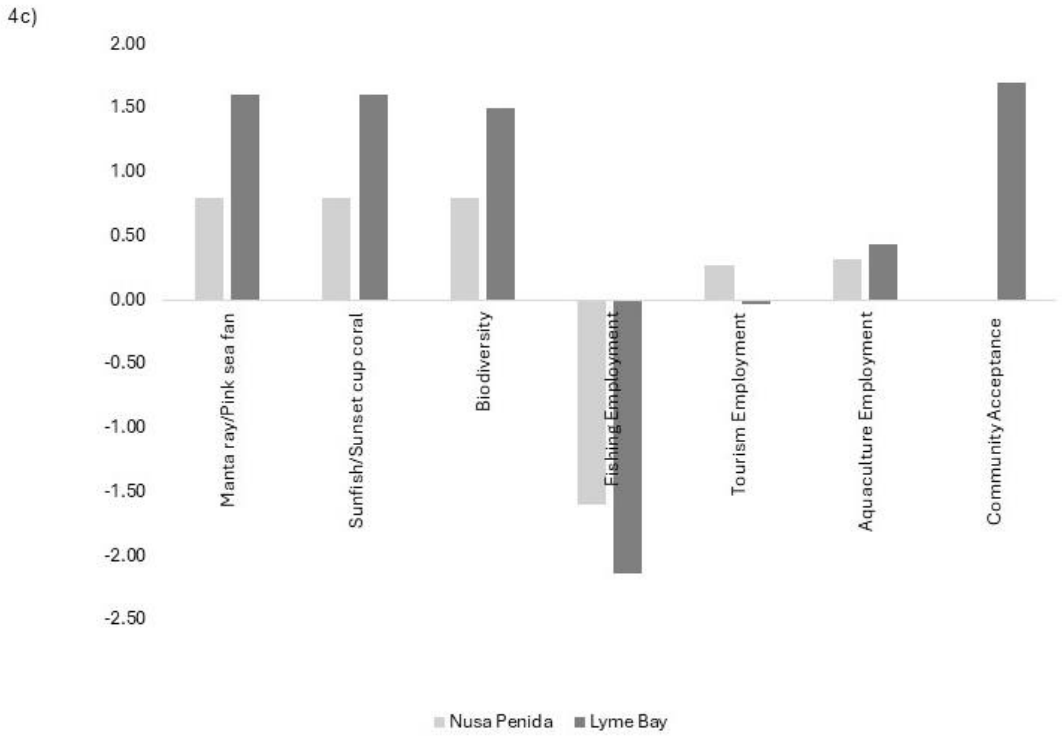
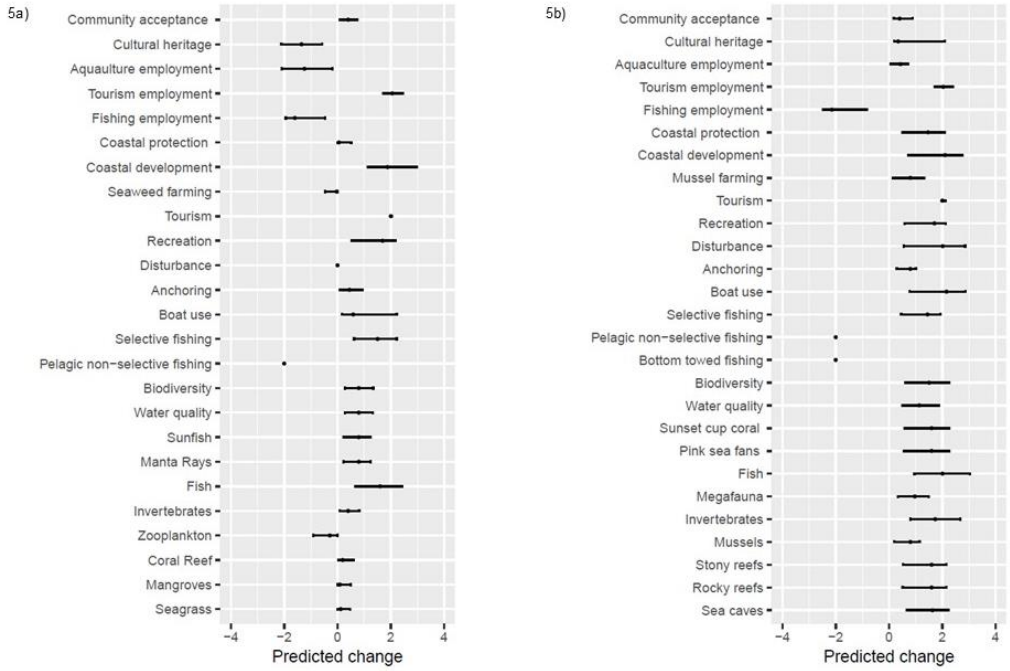


Figure 5. Outputs of BBN prediction for scenario 4 (partial protection – some restrictions on fishing within MPAs). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes between sites.

3.1.3 Restricted fishing and alternative livelihoods scenarios

Scenario 5. Fishing restrictions & increased tourism

This scenario had no impact on coastal protection, seaweed farming and disturbance nodes in Nusa Penida, and decreases were shown for cultural heritage, aquaculture employment, fishing employment, pelagic non-selective fishing and zooplankton. All other nodes were predicted to increase (see Fig. 5a). In Lyme Bay, all nodes were predicted to increase, except for fishing employment, pelagic non-selective fishing and bottom towed fishing, which decreased (see Fig. 5b). For the seven key nodes, increases in tourism employment and community acceptance were roughly equal across both case studies. Fishing employment decreases were larger in Lyme Bay, and aquaculture employment increased in Lyme Bay but decreased in Nusa Penida. The remaining key nodes were predicted to increase in both MPAs but showed larger increase in Lyme Bay (see Fig. 5c).



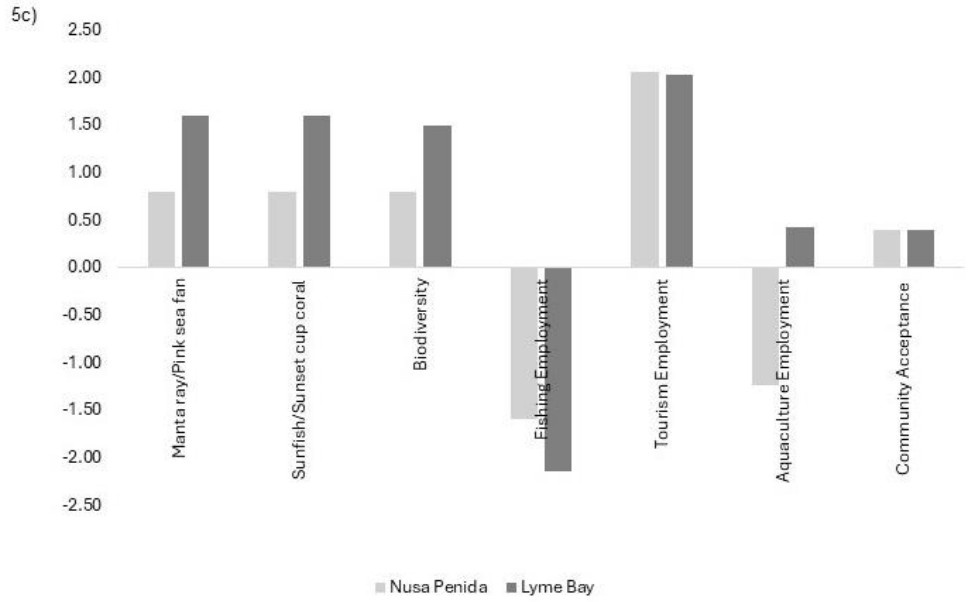
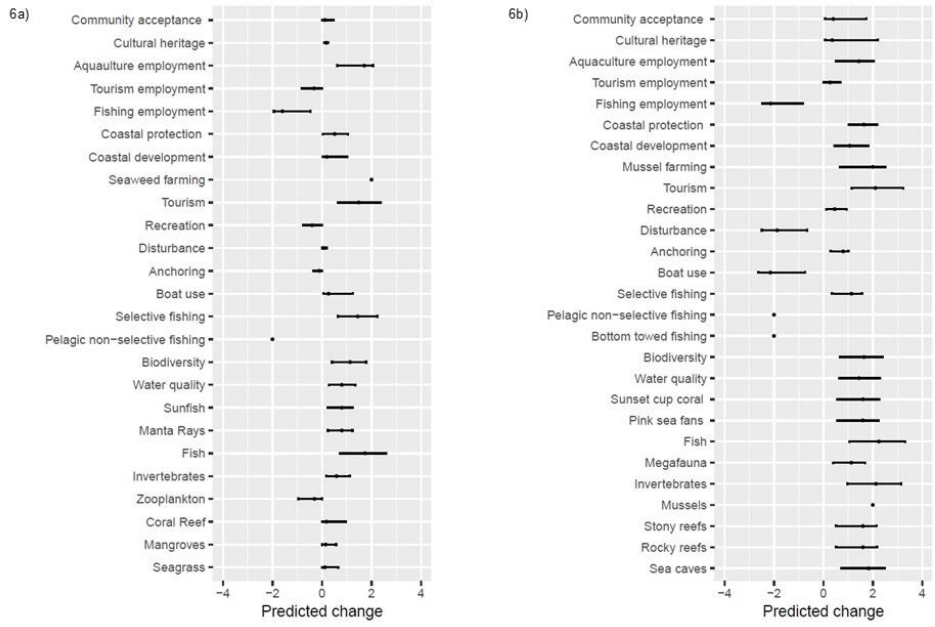


Figure 6. Outputs of BBN prediction for scenario 5 (partial protection - some fishing restrictions combined with increased tourism, within MPAs). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes between sites.

Scenario 6. Fishing restrictions and increased aquaculture

For this scenario Nusa Penida projected decreases in tourism employment, fishing employment, recreation, anchoring, pelagic non-selective fishing, and zooplankton nodes, with increases across all other nodes (see Fig. 6a). In Lyme Bay, decreases were predicted for fishing employment, disturbance, boat use, pelagic non-selective fishing, and bottom-towed fishing, while all other nodes were expected to increase (see Fig. 6b). For the seven key nodes, tourism employment declined in Nusa Penida but increased in Lyme Bay. Fishing employment decreased in both MPAs, with a larger decrease in Lyme Bay. All remaining key nodes showed increases at both sites, however, aquaculture employment increased more in Nusa Penida, whereas increases for the other nodes were greater in Lyme Bay (see Fig. 6c).



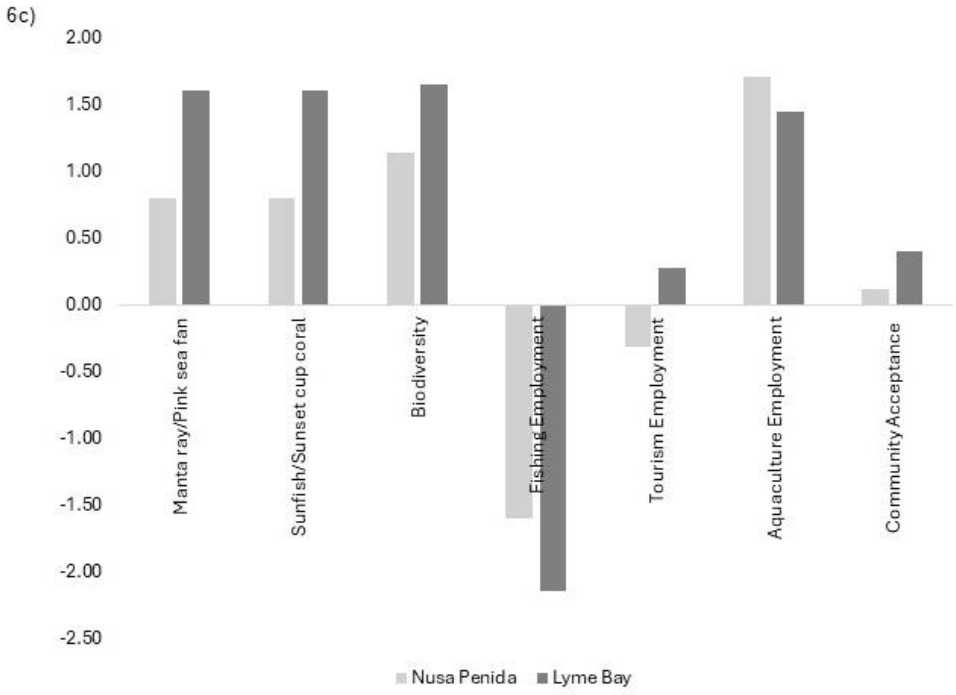


Figure 7. Outputs of BBN prediction for scenario 6 (partial protection - some fishing restrictions combined with increased seaweed farming in Nusa Penida MPA and increased mussel farming in Lyme Bay MPA). (a) Nusa Penida (b) Lyme Bay (c) comparison of key nodes

Nusa Penida MPA

Scenarios that solely decreased fishing activities (scenario 4 & 5) led to improved biological nodes, but reduced fishing employment, and did not result in any increase to community acceptance (figures 4c & 5c). When fishing restrictions were accompanied by other management interventions (scenario 6 & 7), community acceptance showed a minimal increase, in line with higher increases in tourism or aquaculture employment (figures 6c & 7c).

An increase in aquaculture alone (scenario 2) resulted in 2 reduced employment nodes and minimal community acceptance increase, but positive outcomes for biodiversity. Key species show slight decreases (figure 3c). Active restoration (scenario 1) provides the best overall biological and socioeconomic outcome. It shows improvements in all biological key nodes, increases in fishing and tourism

employment, and demonstrates the highest community acceptance of all scenarios, despite a small decrease in aquaculture employment (figure 2c).

Lyme Bay MPA

All scenarios that decrease fishing activity (scenario 4, 5, 6 & 7) result in improved biological nodes and improved community acceptance, but reduce fishing employment (figures 4c, 5c, 6c & 7c). Community acceptance is highest in scenario 3 (NTZ), where biological nodes improved the most (figure 4c).

Fishing restrictions combined with increased aquaculture or tourism (scenarios 6 & 7) result in positive effects on biological nodes and increases in aquaculture and tourism jobs, but create the least increase in community acceptance combined with fishing employment decreases.

Active restoration (scenario 1) led to an increase in all biological nodes, employment nodes, and community acceptance (Figure 2c). However, the realistic probability of being able to create this scenario was evaluated as unlikely for Lyme Bay. Because this scenario consisted of improved habitats through active restoration, with no restrictions on fishing activity, the scenario did not account for any decrease in trawling activity that may, in reality, be required to allow newly established habitats to succeed to the levels anticipated in the scenario. Whilst the same scenario was applied to Nusa Penida, it was considered that this MPA would be able to achieve successful habitat improvements without the need for fishing restrictions, as trawling was not noted to occur in the area, and pelagic fishing for species such as tuna was considered unlikely to cause detriment to restoration efforts.

In contrast, because of an existing, direct relationship between aquaculture increase and trawling decline, which was able to be incorporated into the BBN, and justified by the inability to conduct mobile fishing throughout mussel farm areas, the increased aquaculture scenario (scenario 2) was able to produce positive results whilst still anticipated a reduction in trawling. Increased aquaculture alone resulted in slight negative impact to pink sea fans, no negative impact to sunset cup corals, and a positive impact on biodiversity. All employment nodes and community acceptance increased (figure 3c). Although community acceptance is not as high as with the NTZ

scenario (scenario 3, figure 4c), this is considered the best scenario due to the employment increases, and the lack of feasibility of scenario 1 (active restoration).

3.2 Analysis of suitable governance incentives

The most effective scenario for each reference site is identified here for analysis of (i) the governance incentives that are already implemented in each MPA; and (ii) the governance incentives that could be implemented to achieve the proposed management interventions of each scenario.

3.2.1 Nusa Penida – active restoration (scenario 1)

Table 8. Existing governance incentives taken from Yunitawati and Clifton (2021), and proposed incentives, for creating scenario 1 in Nusa Penida MPA

Category	Incentive	Existing Incentive (Y). Considered priority for strengthening (Y*) Not used (N)	Details of existing incentives	Proposed incentive for Nusa Penida Scenario 1 (Y)	Reason for decision
Economic	i1.Payments for ecosystem services	N		Y	Create funding through carbon credits for mangrove/seagrass restoration, and biodiversity credits for coral reef restoration (Suggett et al. 2023).
	i2.Assigning property rights	N		Y	To facilitate a financial credit system, and give management authority over the area. To create a habitat restoration programme in Indonesia, permits are required (Razak et al. 2022).
	i3.Reducing the	Y*	Traditional fisheries zone restricted to local	N	Not considered in the scope of this scenario

	leakage of benefits		fishers. However, tourism may benefit external operators.		
	i4. Promoting profitable and sustainable fisheries and tourism	Y*	Core zone (2% of MPA) is no take zone. Gear restrictions in traditional fishery zone. Additional measures needed to stop tourism disturbing manta ray and sunfish.	N	Whilst the scenario could naturally provide more sustainable tourism and fishing through ecotourism opportunities and increased fish stocks, there is no promotion of sustainable behaviour included in this scenario.
	i5. Promoting green marketing	N		Y	Active restoration projects could attract tourists who wish to visit these restoration sites, promoting an environmentally friendly tourist attraction.
	i6. Promoting diversified and supplementary livelihoods	N		Y	Local community can gain employment working on habitat restoration projects, creating income opportunity.
	i7. Providing compensation	N		N	No detriment expected to community livelihoods and therefore no compensation required.
	i8. Investing MPA income/funding in facilities for local communities	N		N	Improving local facilities is not within the scope of this scenario.
	i9. Provision of state funding	Y*	Currently exists. Suggestions that increased long-term funding alongside a proposed user fee funding would benefit the MPA.	Y	Whilst carbon/biodiversity credits, as well as restoration tourism fees can fund projects, funding may be required for initial set up, to enable effective management/monitoring, and to be able to achieve

					on large enough scales. This could be through private or state funding.
	i10. Provision of NGO, private sector and user fee funding	Y*	Receives funding from CTC but priority to become self-financing. Proposed entrance fee.	Y	As above, additional funding required for successful projects. Diversity of funding can make projects more secure.
Communication	i11. Raising awareness	Y	Village meetings involving fishers, seaweed farmers, tour operators, government officials, teachers and traditional leaders, to raise awareness.	Y	Raising awareness creates improved engagement with projects from local community (Sebastian et al. 2024).
	i12. Promoting recognition of benefits	Y	As above – awareness on benefits of sustainable fishing	Y	As above.
	i13. Promoting recognition of regulations and restrictions	Y	Zonation maps to highlight restrictions in village, schools and given to boat operators.	N	No regulations on human activity implemented in this scenario.
Knowledge	i14. Promoting collective learning	Y	Village forums allow for collective learning, help shape zones	Y	Collective learning can help produce successful habitat restoration techniques.
	i15. Agreeing approaches for addressing uncertainty	N		N	Although potentially useful, not considered essential in creating habitat improvements.
	i16. Independent advice and arbitration	Y*	CTC who helped initiate the MPA recognised as independent advisor.	Y	Professional advice on achieving successful restoration would be beneficial.

Legal	i17. Hierarchical obligations	Y	National target of 20 million ha by 2020, and Aichi targets/CTI goals. Various laws to improve sustainability.	Y	No clear objectives from legislation for habitat restoration (Razak et al. 2022). However, scenario designed to meet MPA objectives.
	i18. Capacity for enforcement	Y*	Park rangers and community surveillance groups. Concerns that government lack commitment.	N	No regulation put in place, therefore no enforcement required.
	i19. Penalties for deterrence	Y	Up to 6-year penalties for banned destructive fishing. Unclear if effectively applied/ sufficient to deter.	N	As above
	i20. Protection from incoming users	Y*	Traditional fisheries zone is for locals only. No mechanism for identifying locals.	N	Not considered as a requirement of managing restoration projects.
	i21. Attaching conditions to use, property rights, decentralisation, etc.	Y*	Traditional zone for local fishers only. Code of conduct exists for tourism operators. No licence restrictions so non-locals can come to tourism zone.	Y	Property rights (assigned for the facilitation of carbon credits) will need to have conditions attached to ensure correct usage.
	i22. Cross-jurisdictional coordination	N		N	Habitat improvements not expected to need coordination across authorities, as not intervening with other sectors.
	i23. Clear and consistent legal definitions	Y	Legal codification was focused on in CTC meetings for zones.	N	No regulations imposed meaning there is no need for clear legal definitions.
	i24. Clarity concerning jurisdictional	N		N	No action proposed in this scenario to mitigate

	limitations				external influences such as pollution.
	i25. Legal adjudication platforms	N		N	No regulations imposed so no need for this incentive.
	i26. Transparency, accountability and fairness	Y	Made an objective in CTC meetings. Records are publicly available.	Y	Making information on projects transparent to help keep local community members engaged and involved.
Participative	i27. Rules for participation	N		N	No rules imposed in the MPA.
	i28. Establishing collaborative platforms	Y*	Village meetings before MPA designation. Arguably limited influence. Lack of continued collaboration since government takeover.	Y	Involving users considered important in habitat restoration projects, creating support and engagement.
	i29. Neutral facilitation	N		N	Potential disputes seem unlikely, as MPA users not reported to be unaccepting of restoration projects.
	i30. Independent arbitration panels	N		N	No requirement for negotiations as unlikely to face disputes between MPA users.
	i31. Decentralizing responsibilities	Y*	In theory, government empowered as a result of national decentralisation legislation, but responsibilities are not being fulfilled.	Y	Restoration projects often not managed by government in Indonesia, and legislation requires local communities and MPA users to be directly involved (Razak et al. 2022).
	i32. Peer enforcement	Y	Community based enforcement initiatives. Seashore security (local fishers with diving ability) offer surveillance and enforcement alongside rangers.	N	No usage restrictions mean there is no need for enforcement.

	i33. Building trust and the capacity for cooperation	N	Lacking due to absence of district government in taking on its responsibilities	Y	Best practice to involve local community in habitat creation projects, to ensure acceptance and support.
	i34. Building linkages between relevant authorities and user representatives	Y*	CTC meetings were being held, but district government has neglected since taking over.	Y	Good relationships between government, and NGO/project managers as well as representatives of fishery/tourism industries to create support for projects.
	i35. Respecting and building on local customs	Y	Traditions coexist alongside the MPA. Sacred temple zone created to stop boats offending local sensitivities due to divers changing in sight of temple.	Y	Local customs such as traditional fishing grounds and sacred areas should be considered when placing habitat creation projects within the MPA, to support culture and wellbeing.
	i36. Potential to influence higher institutional levels	N		Y	Collaborative governance, inclusive of local communities with local knowledge, could help shape future governance of habitat creation projects.

3.2.2 Lyme Bay – increase in aquaculture (scenario 2)

Table 9. Existing governance incentives (Singer and Jones 2021), and proposed governance incentives for creating scenario 2 (aquaculture increase) in Lyme Bay MPA.

Category	Incentive	Existing Incentive (Y). Considered priority for strengthening (Y*). Not used (N)	Details of existing incentive	Proposed incentive for Lyme Bay scenario 5 (Y). Not proposed (N)	Reason for decision
Economic	i1.Payments for ecosystem services	N		N	Not considered relevant for facilitation of mussel farm.
	i2.Assigning property rights	N		Y	Must apply to Department for Environment, Food & Rural Affairs (DEFRA) for Regulatory/Several Orders. Consent from anyone with right to the fishery area is required (DEFRA 2024).
	i3.Reducing the leakage of benefits	N		Y	Licensing would be implemented to stop unauthorised shellfish extraction from the shellfishery (DEFRA 2024). Protecting spillover stocks from non-local fishers could help satisfy local community.
	i4. Promoting profitable and sustainable fisheries and tourism	Y	Encourages fishing at sustainable levels through voluntary codes of conduct for static fishing and angling size limits. Concerns over spillover benefits for scallop fishery as some areas adjacent to closure not suitable for scallops.	Y	Sustainable approaches for the shellfishery would help gain proposed harvest and spillover outcomes (for example – not overharvesting or overloading ropes past mussels carrying capacity, allowing mussel farms to self-sustain and create

					novel habitat (Caroppo et al. 2012).
	i5. Promoting green marketing	Y	Lyme Bay Reserve Seafood brand can be used by boats using voluntary code of conduct, using i VMS surveillance technology and approved by responsible fishing scheme. Unclear if increased prices caused reduction in catch.	Y	Promoting mussels as sustainable food could help profits and acceptance.
	i6. Promoting diversified and supplementary livelihoods	Y	Recovering reefs is helping the dive charter sector. Not promoted as an alternative livelihood. Blue Marine Foundation (BMF) funded facilities to promote freshness of catches to add value.	Y	The mussel farm could provide jobs and additional income to locals. Improved ecosystems could facilitate income opportunities in tourism/diving sector, which could support mobile fishers who lose some fishing grounds.
	i7. Providing compensation	N		N	Although mobile fishers face displacement (Bridger et al. 2022), this scenario proposes that spillover will benefit these fishers.
	i8. Investing MPA income/funding in facilities for local communities	N		N	Mussel farms proposed as private sector and self-funded. Help with their funding can be attained through The Fisheries and Seafood Scheme (Marine Management Organisation [MMO] 2024), MPA funding not proposed to be required.
	i9. Provision of state funding	Y*	State, private and NGO (BMF) funding for project and infrastructure. However, the same level of resource cannot	N	As above

			continue due to state funding restrictions and increased country wide MPA designation.		
	i10. Provision of NGO, private sector and user fee funding	Y*	As above.	Y	Mussel farms proposed as private sector, self-funded companies.
Communication	i11. Raising awareness	Y	School outreach, distribution of voluntary agreement, media coverage, website and social media, exhibit, video on scallop dredging, to help instil pride in sustainable fishing.	N	This is used to promote the importance of the ecosystem to encourage people to care about complying with MPA rules, therefore not considered beneficial for building mussel farms, which don't require participation.
	i12. Promoting recognition of benefits	Y	Promotes success of conservation measures	Y	Promoting proposed benefits of mussel farms to local community/fishers could help gain community acceptance (Bridger et al. 2022).
	i13. Promoting recognition of regulations and restrictions	Y	IFCA regulations communicated directly. Forum for questions and debates (limited to local group members). Increased awareness leading to increased reports of infringements.	Y	Advising on restrictions in the mussel farming zone on mobile fishing or extraction of mussels without license. If rules in place to protect from outside users, promoting regulations can reduce infringements.
Knowledge	i14. Promoting collective learning	Y	The working group allows for discussion between scientists, regulators, fishers, NGOs etc.	Y	To enable the best execution of mussel farming, for sustainable and successful mussel yields, and success in creating novel habitat and spillover.

	i15. Agreeing approaches for addressing uncertainty	Y	A precautionary approach is taken through proactive risk-based approach of fishing restrictions.	N	Whilst potentially useful, Not considered a key requirement in establishing mussel farms.
	i16. Independent advice and arbitration	Y	Research partnerships with marine scientists to monitor ecological and economic impacts.	Y	Beneficial for creating sustainable mussel farms and avoiding negative ecological impact. For example, knowing where best to place the farm to prevent disturbance.
Legal	i17. Hierarchical obligations	Y	EC Habitat Directive obligations. IFCA bylaws. SI bylaws ban mobile gear.	Y	Need to follow obligations and bylaws.
	i18. Capacity for enforcement	Y*	Satellite VMS to help surveillance, but unregistered boats can still go unnoticed. Input from Navy and Border Force gives strong presence.	Y	To help reduce infringements to protect from leakage of benefits.
	i19. Penalties for deterrence	Y	Successful prosecutions of illegal scallop dredger. Prosecutions are difficult.	Y	As above
	i20. Protection from incoming users	Y	Infringements have reduced. Outsiders sometimes break mobile gear regulations	Y	To ensure benefits are felt in local community
	i21. Attaching conditions to use, property rights, decentralisation, etc.	Y	Adherence to the MPA restrictions is a condition of fishing.	Y	Conditions of running mussel farm need to adhere to MPA objectives. For example, not negatively impacting protected species or habitats.

	i22. Cross-jurisdictional coordination	Y*	Proposed joint IFCA management plan could help coordinate. Currently regulatory methods differ due to different challenges in different jurisdictions.	Y	Coordination from all managing authorities ensure all regulations adhered to.
	i23. Clear and consistent legal definitions	Y*	IFCAs managing the site increase the need for constant legal direction. Steered from Natural England, MMO and DEFRA.	Y	Clear legal definitions would help ensure correct management.
	i24. Clarity concerning jurisdictional limitations	N		N	Whilst factors such as pollution are often outside of MPA jurisdictional limitations, it is not within the scope of this management scenario to address this.
	i25. Legal adjudication platforms	Y	Prosecuted fishers have the right to appeal	Y	Continuing to allow prosecuted fishers the right to appeal.
	i26. Transparency, accountability and fairness	Y	Information from MMO and IFCAs publicly available	Y	Statutory requirement for public access to information could make community more trusting and accepting.
Participative	i27. Rules for participation	N		Y	For those granted use in mussel farm areas, rules will apply, such as not taking species legally reserved by the mussel farm.
	i28. Establishing collaborative platforms	Y	Discussions between users and between regulators and users.	Y	Collaboration between users to ensure acceptance.
	i29. Neutral facilitation	Y*	BMF have facilitated as an external group. IFCA reps have been proposed as leaders of the working group which could undermine this.	Y	Would help with negotiations between shellfisheries and fishers.

	i30. Independent arbitration panels	N		N	As this scenario is an extension of existing mussel farming in the area, it is considered unlikely to benefit from arbitrator advice or decision making.
	i31. Decentralizing responsibilities	Y	Most decentralised to the two IFCAs and some to the working group.	Y	As already in place, these could remain, allowing collaboration with MPA users in decision making.
	i32. Peer enforcement	Y	Infringements reported by fishers, anglers, and members of the public.	Y	As already in place, infringements from outside users could be reported by community.
	i33. Building trust and the capacity for cooperation	Y*	Social capital has greatly increased. Voluntary agreements do not directly reduce fishing effort more of a symbolic gesture.	Y	Listening to concerns and working to avoid displacement/reduced fishing yield in mussel farm design could lead to more acceptance from fishing community (Bridger et al. 2022).
	i34. Building linkages between relevant authorities and user representatives	Y	Limited to static fishers and representatives of the agencies (through the working group).	Y	Authorities would benefit from close relationships with mussel farm owners to ensure mussel farms are working towards MPA objectives/ conservation goals.
	i35. Building on local customs	N		Y	Allowing for negotiations with MPA users to protect customs such as traditional fishing practices or recreation within the MPA. For example, considering the location of the mussel farm or allowing scallop diving/recreational fishing to take place within the farm area.

	i36. Potential to influence higher institutional levels	Y	The working group has increased the perceived 'voice' and influence of MPA users on higher institutional levels in DEFRA.	Y	The consultation of MPA users in mussel farm design can demonstrate coevolutionary governance.

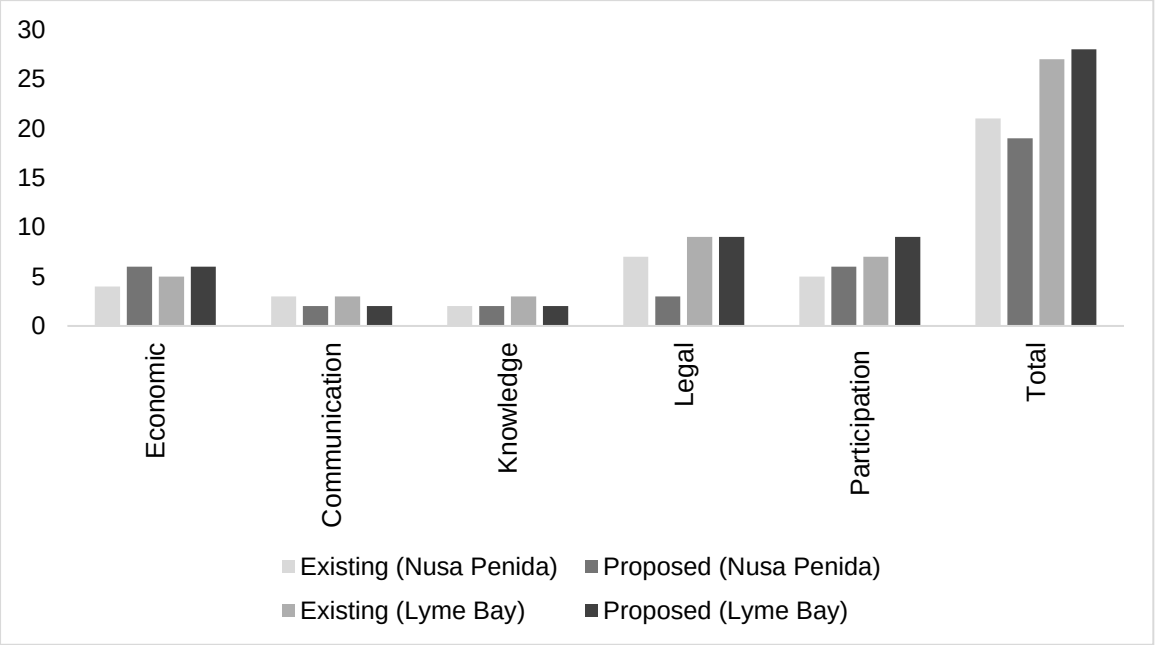


Figure 8. Comparison of existing governance incentives at Nusa Penida MPA and Lyme Bay MPA, and proposed governance incentives needed at each MPA for successful active habitat restoration in Nusa Penida (scenario 1), and mussel farming increases in Lyme Bay (scenario 4).

The proposed governance incentives for active restoration as a management approach in Nusa Penida suggests the use of more incentives from the economic and participative categories than currently in place at the MPA, but less from the communication and legal categories. The same number of incentives from knowledge categories were suggested, and two less incentive overall (figure 8).

The proposed governance incentives for mussel farming as a management approach in Lyme Bay suggests the use of one more incentives than currently used at the MPA. The use of more incentives from economic and participative categories are considered to be beneficial, but less communication and knowledge incentives than currently in place (figure 8).

In comparison to the increased mussel farming scenario in Lyme Bay, active restoration projects in Nusa Penida were proposed to need nine less incentives overall, from legal and participative categories. The number of incentives proposed from the communication, knowledge and economic categories were the same for both scenarios (figure 8).

4. Discussion

Habitat creation as an MPA management approach in this study resulted in predicted positive outcomes for both sites. In Nusa Penida, active restoration was predicted to benefit ecosystems, employment, and community acceptance, while in Lyme Bay the scenario's effectiveness was limited by lack of protection from trawling. Increased mussel farming provided the most successful scenario for Lyme Bay, through predicted ecological benefits, increased job opportunities and community support. In comparison, restricted fishing as an MPA management approach resulted in predicted ecological benefits within MPAs but led to fishing employment declines, though introducing alternative livelihoods helped offset employment losses. Community acceptance generally increased with job opportunity increases or ecosystem improvements, with the latter having a greater influence in Lyme Bay than in Nusa Penida.

4.1 Restricted fishing

Restricting or banning fishing practices in this study was not considered the most successful MPA management approach, as although positive ecological outcomes were predicted, fishing employment was predicted to decline. In line with these findings, evidence of ecological benefit following fishing restrictions exists for both case studies. Early surveys in Nusa Penida after MPA establishment showed

increases in fish biomass and density (Yunitawati and Clifton 2021). In Lyme Bay, an increase in macro epi-benthic species was identified within the first few years of SI establishment (Sheehan et al. 2013), and later, findings identified a 430% increase in exploited fish taxa, and a 370% increase in exploited species abundance (Davies et al. 2021). These findings demonstrate how restrictive approaches can be compatible with conservation objectives (Lester et al. 2009). However, socioeconomic aspects of an MPA can suffer. Trawling bans in Lyme Bay led to reports of reduced income and job satisfaction, increased fishing effort, and heightened stress, conflict, and inequity amongst mobile-gear fishers (Rees et al. 2016).

Whilst this study evaluated outcomes within the boundaries of the MPA, fishing restrictions have potential to create sustainable fishing opportunities to areas outside MPA boundaries through spillover of commercial species (Bennett and Dearden 2014). If spillover was to offset lost fishing opportunities within an MPA, ecological and socioeconomic trade-offs could be reduced. However, potential displacement issues can occur, such as the increased time and costs faced in reaching new fishing grounds, increased competition (Sowman and Sunde 2018), and lag time between fishing restriction introduction and spillover benefits (Bennett and Dearden 2014).

It is important to consider that whilst the introduction of fishing restrictions can be detrimental to fishers' livelihoods in the short-term, such measures can provide long-term protection of fish stocks. Continuous overfishing has historically led to complete collapse of commercial fisheries, as seen in Newfoundland, Canada, where overextraction led to a multi-decade ban on commercial fishing for Northern cod, causing job and income losses for tens of thousands of people (Mason 2002). Introducing limitations on fishing activity through practices such as fishing area closures, catch quotas and minimum landing size rules can bring fishing levels below maximum sustainable yield (Worm et al. 2009; Froese et al. 2011), and stop the extraction of immature fish (Froese et al. 2008), allowing fish stocks to continuously replenish, which in the long-term can protect fishers from fish stock collapses and in some cases offer increased catch per unit effort (CPUE) (Laë 1997; Vandeperre et al. 2011).

4.1.1 Restricted fishing and alternative livelihoods

The provision of alternative livelihood opportunities to support fishers disadvantaged by restrictions was investigated in this study, through proposed increases in tourism or aquaculture. These scenarios predicted reduced fishing employment, but increased alternative employment opportunities, led to ecological benefit, and predicted some increases in community acceptance in both case studies.

Many fishers in Nusa Penida have transitioned to seaweed farming or tourism jobs after prohibition of harmful fishing practices (Lehmann and Rungby 2017; Gerungan and Chia 2020; Andréfouët et al. 2021), demonstrating successful utilisation of alternative livelihoods at this MPA. Whilst the literature does not suggest such employment plasticity in Lyme Bay, reports exist of mobile-gear fishers diversifying to static fishing practices following trawling bans (Rees et al. 2021).

Whilst these alternative livelihoods can benefit displaced fishers, and as a result bring fishing management approaches more in line with socioeconomic objectives, fishers may still face inequities that need consideration. Fishers may not have required skills, or education to benefit from the availability of alternative livelihoods (Habib et al. 2023), and alternative industries, such as seaweed farming in Nusa Penida, can be less profitable or more unreliable (Putra 2023). Opportunities may be taken by non-locals, such as diving businesses in Nusa Penida which mostly come from mainland Bali (Gerungan and Chia 2020), meaning locals often fail to benefit from tourism increases (Badalamenti et al. 2000; Bennett and Dearden 2014).

Fishers often value their occupation as a ‘way of life’ over a means of earning income (Brookfield et al. 2005; Blount and Pitchon 2007; Kimbu et al. 2022), and cultural identity, sense of self and wellbeing can be negatively affected by loss of a valued job role (Brookfield et al. 2005). Whilst increased tourism can offer economic opportunity, the presence of more tourists can price out locals through increased property prices (González-Pérez 2020), and reduce locals’ quality of life through denied access to amenities, permanent changes in lifestyle, and increased economic dependency (García-Buades et al. 2022).

Although restricted fishing scenarios in this study predicted fishing employment decline, when considering the opportunity for spillover, protected fish stocks and ecological benefit these scenarios offer the potential as successful management approaches if implemented governance were to ensure equitable treatment of disadvantaged fishers. For example, The wellbeing of displaced fishers was improved at Lyme Bay through the establishment of a committee that promoted better collaboration of user groups including fishers (Rees et al. 2021), as well as the provision of facilities to support the new livelihoods of those affected (Renn et al. 2024). Additional governance, such as the introduction of compensation (Spalding et al. 2016) and protection against leakage of spillover benefits from incoming users (Jones et al. 2011) could further aid in building a successful and equitable MPA management approach through fishing restrictions or NTZs.

4.2 Habitat creation

4.2.1 Mussel farming

A proposed expansion of mussel farming in Lyme Bay was predicted to benefit ecosystems, jobs and community acceptance. This was the only feasible scenario predicted to increase all 3 employment categories, whilst displaying ecological improvements, and therefore was considered the best management approach proposed for Lyme Bay. Despite mussel farms creating some physical barriers to mobile fishing activity (Bridger et al. 2022), improved ecosystems and increased fish stocks were expected to increase fishing and tourism employment, in addition to increased aquaculture employment.

In support of these predictions, mussel ropes and seabed below the existing Lyme Bay mussel farms have been found to home increased biodiversity and abundance of fish and invertebrate species (Mascorda-Cabre et al. 2024b), including commercial species of lobster and crab (Mascorda-Cabre et al. 2021; Bridger et al. 2022; Bridger et al. 2024; Mascorda-Cabre et al. 2024b). Some fishers at Lyme Bay

report better fishing in the area since the farm's establishment (Mascorda Cabre et al. 2021; Bridger et al. 2022), with most suggesting no impact on their fishing locations, with positive perceptions of improved fish stock potential. Some fishers have shown negative outlooks, reporting displacement and increased fishery competition due to loss of fishing grounds. Drivers of these differing perceptions were unclear, and may stem from lack of obvious short-term benefits to landings, which can take years to materialise (Bridger et al. 2022). Perhaps attitudes toward the farm would be more positive without the MPA's current trawling ban, as proposed in this scenario, or compensatory measures may be needed for mobile fishers who lose access to fishing grounds while waiting for spillover benefits to develop. Community acceptance was predicted to increase in this scenario, however this node represented the whole community and may misrepresent fishers' acceptance levels.

The pink sea fan was predicted to marginally decline in this scenario, likely due to the lack of protection from trawling activity (Pikesley et al. 2016). As a long-lived species with specific habitat needs, their recovery can take over 20 years, and require protection from direct damage (Kaiser et al. 2018). This suggests that additional trawling restrictions may be required in the MPA to protect this species and others with similar life history traits. This highlights the importance of considering individual species in MPA design, as conservation methods benefitting one group may not protect another (Edgar et al. 2014). Fishing restrictions combined with increased mussel farming (scenario 6) resulted in positive outcomes for the pink sea fan, but negatively impacted fishing employment. Further investigation of this scenario could help identify optimal levels of fishing restrictions and mussel farm expansion, in finding positive outcomes for both of these aspects.

While this scenario may not fully support all ecosystem aspects, it offers potential for reducing restrictive measures by introducing novel habitats and spillover. The scenario was considered likely to require stronger economic and participative governance than currently in place, due to the operational regulations required in comparison to fishing restrictions. This includes assigning property rights for privately owned shellfisheries, enforcing protection against unauthorised extraction, and implementing participatory rules, to regulate species extraction (DEFRA 2024).

4.2.2 Seaweed farming

Expanding seaweed farming practices within Nusa Penida MPA had mixed predicted outcomes for the ecosystem. Biodiversity and fish stocks were expected to increase, whilst habitats such as coral reef and seagrass were predicted to marginally decline, as well as the abundance/condition of manta rays and sunfish. Although aquaculture employment opportunities rose, fishing and tourism jobs were predicted to decline. This may be due to loss of recreational grounds or access (Firdausy and Tisdell 1991), decreases in megafauna and coral reefs which are important for attracting tourism (Yunitawati and Clifton 2021), or simply due to a larger amount of people working in the aquaculture trade, taking workforce away from the other industries. Community acceptance in this scenario showed little increase, likely due to reduced employment opportunities, and lack of ecological improvements. Whilst seaweed farming is important for Nusa Penida's local economy (Suwendri et al. 2021), this scenario's limited economic and environmental benefit suggests it is unlikely to be a successful management approach.

Seaweed farming can provide habitat and food for juvenile fish and invertebrates (Tano et al. 2016), however, responses to seaweed farms can be species-specific, and overall positive effects are debated. For example, sessile species that benefit from the creation of novel habitat, may fall into an ecological trap, if harvested along with the seaweed itself (Theuerkauf et al. 2022). Seaweed farms can also have negative impacts on surrounding habitats and species communities, due to light and nutrient competition and damage from farming techniques (Eklöf et al. 2016; Kelly et al. 2020). The environmental impacts of the seaweed farming that takes place in Nusa Penida MPA have not been widely researched (authors observation), with some research suggesting no adverse effects on water quality (Firdausy and Tisdell 1991). The negative outcome for megafauna and habitats in this scenario could be caused by lack of protection from other threats due to the absence of activity restrictions. For example, bycatch risk is a major threat to manta rays (IUCN 2015), and would still be present, alongside tourism activity which can damage reefs through trampling (Santos et al. 2015).

Seaweed farming provides important income and livelihood diversification opportunities to local communities surrounding Nusa Penida MPA (Carter et al. 2014). However, reliability of this industry fluctuates, due to failed crops and low selling prices (Putra 2023), and seaweed farming has previously ceased in Nusa Lembongan (Andréfouët et al. 2021), where many community members have diversified to the increasing tourism trade (Suwendri et al. 2021). Preference for tourism jobs is evident, which are reported to provide an easier and more reliable income (Andréfouët et al. 2021; Putra 2023). Although an important part of the socioeconomics of Nusa Penida MPA, expanding seaweed farms lacks potential to meet conservation objectives, and could harm livelihoods if causing detriment to the tourism industry, or reductions in charismatic species such as manta rays.

4.2.3 Active restoration

Increasing the abundance and quality of key habitats within both MPAs predicted positive outcomes for jobs and ecosystems. However, achieving this scenario in Lyme Bay, without implementing further trawling bans, was deemed unrealistic, and because the scenario consisted of an expected level of increase in habitat quality, while no trawling ban was implemented, it was deemed that this type of scenario would not be possible to achieve. Passive restoration, through NTZs (already considered in scenario 3 of this study), shows the most effective way of improving these habitats. In comparison, damaging fishing techniques in Nusa Penida, such as cyanide and blast fishing, are nationally banned (Tranter et al. 2022), and therefore would not continually degrade restoration efforts with such intensity.

Active restoration predicted the best overall results for Nusa Penida, with positive outcomes for ecosystems, despite no proposed fishing restrictions. Fishing and tourism jobs increased, leading to a decrease in the amount of people working in aquaculture. Community acceptance was predicted to improve, and due to a documented preference for tourism jobs (Andréfouët et al. 2021), the community could likely be accepting of this scenario, particularly if increased fishing opportunities and improved ecosystems were to transpire.

Active restoration projects of this kind have often demonstrated ecological improvements in Indonesia. For example, artificial reefs in Bali have increased fish abundance and biodiversity (Boakes et al. 2022); coral cover has increased following active restoration efforts of degraded reefs in Pulau Badi (Williams et al. 2019); and fishers reported increased fish size and quantity after mangrove restoration projects in North Java (Debrot et al. 2022). In Nusa Penida, ongoing restoration efforts, including mangrove planting and coral restoration (CTC 2024), have reported early signs of success, such as increased fish abundance and structural complexity of coral reefs (Indo Ocean Project 2024).

These restoration projects can offer economic opportunities through ecotourism (Blanton et al. 2024), and labour jobs for locals. In Bali, a coral restoration project has created 20 jobs for local fishers, supporting 12 families (Seatrees 2025). This benefit was not accounted for in this study, but represents the opportunity to provide an alternative income from damaging fishing practices, whilst helping improve ecosystems (Blanton et al. 2024). Improved ecosystems can also enhance tourism, through improved recreational diving experiences (Claudet and Pelletier 2004; Kirkbride-Smith et al. 2016), and following the protection of mangroves Nusa Penida, community members have benefitted from new income opportunities through mangrove tours (Carter et al. 2014; Ginantra and Sundra 2023). However, as previously discussed, increased tourism must be adequately managed to prevent negative social and environmental consequences.

Whilst this scenario allows the continuation of fishing practices at current levels, it is likely that restricted usage measures would need implementing to allow for successful ecosystem improvements (Debrot et al. 2022). Habitats can take time to establish, and coral fragments, for instance, are highly vulnerable in their early stages and may experience high mortality rates (Wilson and Harrison 2005). Fish stocks can also take time to increase. For example, restored mangroves in Indonesia took over a decade to enhance local fisheries, with premature harvesting of nursery fish potentially undermining long-term spillover benefits (Debrot et al. 2022).

For effective management in active restoration, many legal governance incentives currently used at Nusa Penida MPA were considered unnecessary and more economic incentives were considered important. Legal incentives were deemed less

important due to this scenarios' less restrictive nature, and therefore incentives such as capacity for enforcement, penalties for deterrence and consistent legal definitions are redundant. Proposed increases in economic governance were due to the prospect of generating funding through carbon credits, meaning assigning property rights, and creating capacity for payments for ecosystem services, were required.

Whilst the need for restrictions, at least in the short-term, has been acknowledged for this scenario, this study highlights the potential for active restoration to support both ecological and socioeconomic objectives. There may be elements of short-term loss for long-term gain, which reinforces the importance of adequate governance for support and cooperation of potentially displaced fishers, as previously discussed.

4.3 Location-specific differences

Both case studies showed different responses to management approaches, driven by major threats, local ecosystems, and socioeconomic characteristics. The threat that scallop dredging poses to benthic habitats in Lyme Bay, meant restricted fishing scenarios predicted better ecological improvements compared to Nusa Penida, where pelagic fishing techniques are most common (Ruchimat et al. 2013). Differences in aquaculture types meant the suitability of aquaculture operations as a management approach was more successful in Lyme Bay, due to better outcomes for ecosystems from mussel farms compared to seaweed farms. Other aquaculture opportunities that an MPA may be suitable for, could potentially be damaging to the environment, and not operate as an MPA management approach at all. Active habitat restoration in place of fishing restrictions was anticipated to offer ecological and socioeconomic benefits for both MPAs, but was not considered feasible in Lyme Bay due to lack of protection from trawling.

Lyme bay displayed better overall community acceptance from ecological gain, despite employment loss. Whilst ecological benefit was of importance for community acceptance in Nusa Penida, its influence on community support was not considered as strong. Differences in acceptance arose from different community priorities, due to variations in the needs of local people. Nusa Penida is recognised as the poorest

area in the Bali province (Swara et al. 2018), whereas communities surrounding Lyme Bay have a presence of wealthy homeowners (Mosaic 2021). Therefore it was considered that some of this community would less likely to be concerned with loss of income opportunity.

Nusa Penida's local community displays a high willingness to diversify job roles, which is not documented in Lyme Bay. This may indicate differences in attitudes, as those from lower socioeconomic status are more likely to choose jobs for income and security, over personal preference (Sheehy-Skeffington and Rea 2017). Local fishers' dissatisfaction of fishing restrictions is well documented in Lyme Bay (Renn et al. 2024), which to the best of the author's knowledge, is not documented in Nusa Penida. Lyme Bay is a historic fishing area (Mascorda-Cabre et al. 2024a), whilst Nusa Penida's economy has historically derived from agriculture (Suwendri et al. 2021), perhaps suggesting difference in community's cultural ties to the fishing industry. However, it is also possible that fishers' wellbeing is better documented at Lyme Bay. Research on the global south is often lacking, and groups are often underrepresented, due to language barriers and lack of financial support (Barbosa et al. 2023).

When evaluating suitable governance, mussel farming was found to need more incentives than active restoration, and a higher need for legal incentives due to the need for ownership rights and restrictions. More participative incentives were also considered important, due to the need to gain support and cooperation for these restrictions. In comparison, active restoration was considered to require fewer incentives overall due to less need for enforcement and regulation. The need for less governance could make providing adequate governance more attainable, giving an MPA better chance of successful operation.

4.4 Model limitations

BBNs have been used in many disciplines, and when tested have shown to correctly predict system outcomes (Stafford et al. 2015). However, BBNs can incur limitations. Continuous data used for the model needs to be discretized into categorical values,

which can result in loss of precision and obscure key variations in data, potentially affecting accuracy of predictions (Landuyt et al. 2013). The model represents steady-state conditions, and therefore does not allow for exploration of different dynamics over time (Death et al. 2015). Whilst outputs provide a directional expectation, predictions are not quantitative, meaning specific values or measures are not possible (Dominguez Almela et al. 2024).

Specifically in this study, some nodes represented large groups – such as all fish species within the ‘fish’ node, and the ‘community acceptance’ node referring to the entire community. This meant predictive outcomes showed an overall directional prediction, but not for specific species or user groups. With further research, the creation of more specific nodes could allow for more specific predictions. For example, exploring the difference in responses of commercial, reef or pelagic fish could help better understand the outcome for species that are important for different objectives. There may be external influences that could impact scenario outcomes, such as outside users benefiting from increased economic opportunities within the MPA, which could result in less employment opportunities for local individuals. Integrating these aspects into the BBN could help paint a more comprehensive picture of the outcomes of these scenarios.

4.5 Conclusion

The predicted outcomes of this study indicate that habitat creation, through either active habitat restoration or the production of novel habitats through low trophic-level aquaculture can provide positive effects for ecological and socioeconomic components of MPAs. Potential is recognised in increasing ecosystem health, creating job opportunities and providing fishery benefits through enhanced fish stocks. Whilst it is evident that trade-offs will likely continue to occur in MPA design through conflicting conservation and socioeconomic objectives, this study highlights how habitat enhancements can help reduce gaps in these trade-offs, through less reliance on restrictive fishing measures for increased ecosystem health. Whilst it is recognised that individual MPAs differ in their potential for particular management

approaches, and that different approaches have different governance needs, the outcome of this study provides an informed prediction on how MPAs could operate more effectively in meeting conservation and socioeconomic objectives.

References

Advani, S., Rix, L.N., Aherne, D.M., Alwany, M.A. and Bailey, D.M., 2015. Distance from a fishing community explains fish abundance in a no-take zone with weak compliance. *Plos one*, 10(5), e0126098

Allen, G.R., 2008. Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 18(5), 541-556.

Andréfouët, S., Dewantama, I.M.I. and Ampou, E.E., 2021. Seaweed farming collapse and fast changing socio-ecosystems exacerbated by tourism and natural hazards in Indonesia: A view from space and from the households of Nusa Lembongan island. *Ocean & Coastal Management*, 207, e105586.

Badalamenti, F., Ramos, A.A., Voultsiadou, E., Lizaso, J.S., D'anna, G., Pipitone, C., Mas, J., Fernandez, J.R., Whitmarsh, D. and Riggio, S., 2000. Cultural and socio-economic impacts of Mediterranean marine protected areas. *Environmental conservation*, 27(2), 110-125.

Barbosa, C.C., Rock, L.A., Curtis, A.N., Sharitt, C.A. and Rogers, P., 2023. Conducting Communication, Research, and Education from Climate Change Perspectives. *Limnology and Oceanography Bulletin*, 32(2).

Bennett, N.J. and Dearden, P., 2014. From measuring outcomes to providing inputs: Governance, management, and local development for more effective marine protected areas. *Marine Policy*, 50, 96-110.

Bhadarka, M., Bamaniya, P., Bamaniya, M., Kharadi, N. and Sikotariya, H., 2023. Exploring the Crucial Role of Mangroves: Mitigating Soil Erosion and Enhancing Water Purification in Coastal Ecosystems. *Trends in Agriculture Science*, 3.

Blanton, A., Ewane, E.B., McTavish, F., Watt, M.S., Rogers, K., Daneil, R., Vizcaino, I., Gomez, A.N., Arachchige, P.S.P., King, S.A. and Galgamuwa, G.P., 2024. Ecotourism and mangrove conservation in Southeast Asia: Current trends and perspectives. *Journal of Environmental Management*, 365, e121529.

Blount, B. and Pitchon, A., 2007. An anthropological research protocol for marine protected areas: creating a niche in a multidisciplinary cultural hierarchy. *Human Organization,* 66(2), 103-111.

Boakes, Z., Hall, A., Jones, G., Prasetyo, R., Stafford, R. and Yahya, Y., 2022. Artificial coral reefs as a localised approach to increase fish biodiversity and abundance along the North Bali coastline. *AIMS Geosciences*, 8(2), 303-325.

Bridger, D., Attrill, M.J., Davies, B.F., Holmes, L.A., Cartwright, A., Rees, S.E., Cabre, L.M. and Sheehan, E.V., 2022. The restoration potential of offshore mussel farming on degraded seabed habitat. *Aquaculture, Fish and Fisheries*, 2(6), 437-449.

Bridger, D., Attrill, M.J., Rees, S.E. and Sheehan, E.V., 2024. The aggregation effect of offshore mussel farming on pelagic fishes. *Aquaculture, Fish and Fisheries*, 4(2), e165.

Brookfield, K., Gray, T. and Hatchard, J., 2005. The concept of fisheries-dependent communities: a comparative analysis of four UK case studies: Shetland, Peterhead, North Shields and Lowestoft. *Fisheries Research*, 72(1), 55-69.

Brown, K., Adger, W.N., Tompkins, E., Bacon, P., Shim, D. and Young, K., 2001. Trade-off analysis for marine protected area management. *Ecological economics*, 37(3), 417-434.

Buglass, S., Reyes, H., Ramirez-González, J., Eddy, T.D., Salinas-de-León, P. and Jarrin, J.M., 2018. Evaluating the effectiveness of coastal no-take zones of the Galapagos Marine Reserve for the red spiny lobster, Panulirus penicillatus. *Marine Policy,* 204-212.

Carneiro, M. and Martins, R., 2022. Destructive fishing practices and their impact on the marine ecosystem. *In*: Filho, W.L., Azul, A.M., Brandii, L., Salvia, A.L. and Wall, t., eds. *Life below water*. Springer International Publishing, 295-304.

Caroppo, C., Giordano, L., Palmieri, N., Bellio, G., Bisci, A.P., Portacci, G., Sclafani, P. and Hopkins, T.S., 2012. Progress toward sustainable mussel aquaculture in Mar Piccolo, Italy. *Ecology and Society*, 17(3), 204-212.

Carter, E., Welly, M. and W. Sanjaya, 2014. *Lessons Learned in the Development and Establishment of the Nusa Penida Marine Protected Area, 2008 – 2014*. Coral Triangle Center, 46.

Celis-Hernandez, O., Villoslada-Peciña, M., Ward, R.D., Bergamo, T.F., Perez-Ceballos, R. and Girón-García, M.P., 2022. Impacts of environmental pollution on mangrove phenology: Combining remotely sensed data and generalized additive models. *Science of The Total Environment*, 810, e152309.

Claudet, J. and Pelletier, D., 2004. Marine protected areas and artificial reefs: A review of the interactions between management and scientific studies. *Aquatic Living Resources*, 17(2), 129-138.

Claudet, J., 2018. Six conditions under which MPAs might not appear effective (when they are). *ICES Journal of Marine Science*, 75(3), 1172-1174.

Conners, M.G., Sisson, N.B., Agamboue, P.D., Atkinson, P.W., Baylis, A.M., Benson, S.R., Block, B.A., Bograd, S.J., Bordino, P., Bowen, W.D. and Brickle, P., 2022. Mismatches in scale between highly mobile marine megafauna and marine protected areas. *Frontiers in Marine Science*, 9, e897104.

Convention on Biological Diversity, 2022. *Final text of Kunming-Montreal Global Biodiversity Framework.* Montreal: Convention on Biological Diversity.

Coral Triangle Centre, 2019. *Nusa Penida MPA Learning Site.* Indonesia: Coral Triangle Centre.

Coral Triangle Centre, 2024. *CTC Launches Adopt-a-Mangrove Program to Mitigate Climate Change and Restore Nusa Penida MPA's Mangrove Ecosystems.* Bali: Coral Triangle Centre. Available from: https://www.coraltrianglecenter.org/2024/11/18/ctc-launches-adopt-a-mangrove-program-to-mitigate-climate-change-and-restore-nusa-penida-mpas-mangrove-ecosystems/. [Accessed January 2025].

Corrigan, S., Smale, D.A., Tyler, C.R. and Brown, A.R., 2024. Quantification of finfish assemblages associated with mussel and seaweed farms in southwest UK provides evidence of potential benefits to fisheries. *Aquaculture Environment Interactions*, 16, 145-162.

Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (1992] OJ L206/7.

Damastuti, E., de Groot, R., Debrot, A.O. and Silvius, M.J., 2022. Effectiveness of community-based mangrove management for biodiversity conservation: A case study from Central Java, Indonesia. *Trees, Forests and People*, 7, 145-162.

Davenport, J. and Davenport, J.L., 2006. The impact of tourism and personal leisure transport on coastal environments: a review. *Estuarine, coastal and shelf science*, 67(1-2), 280-292.

Davies, T.E., Epstein, G., Aguilera, S.E., Brooks, C.M., Cox, M., Evans, L.S., Maxwell, S.M., Nenadovic, M. and Ban, N.C., 2018. Assessing trade-offs in large marine protected areas. *PLoS one*, 13(4), e0195760.

Davies, B.F., Holmes, L., Rees, A., Attrill, M.J., Cartwright, A.Y. and Sheehan, E.V., 2021. Ecosystem Approach to Fisheries Management works – How switching from mobile to static fishing gear improves populations of fished and non-fished species inside a marine-protected area. *Journal of Applied Ecology*, 58(11), 2463-2478.

Death, R.G., Death, F., Stubbington, R., Joy, M.K. and van den Belt, M., 2015. How good are Bayesian belief networks for environmental management? A test with data from an agricultural river catchment. *Freshwater biology*, 60(11), 2297-2309.

Debrot, A.O., Plas, A., Boesono, H., Prihantoko, K., Baptist, M.J., Murk, A.J. and Tonneijck, F.H., 2022. Early increases in artisanal shore-based fisheries in a Nature-based Solutions mangrove rehabilitation project on the north coast of Java. *Estuarine, Coastal and Shelf Science*, 267, e107761.

de los Santos, C.B., Olivé, I., Moreira, M., Silva, A., Freitas, C., Luna, R.A., Quental-Ferreira, H., Martins, M., Costa, M.M., Silva, J. and Cunha, M.E., 2020. Seagrass meadows improve inflowing water quality in aquaculture ponds. *Aquaculture*, 528, e735502.

de Oliveira Júnior, J.G.C., Campos-Silva, J.V., Santos, D.T.V., Ladle, R.J. and da Silva Batista, V., 2021. Quantifying anthropogenic threats affecting Marine Protected Areas in developing countries. *Journal of Environmental Management*, 279, e111614.

Department for Environment, Food & Rural Affairs, 2024. *Shellfisheries: Several Orders and Regulating Orders*. United Kingdom: GOV.UK. Available from: www.gov.uk/guidance/shellfisheries-several-orders-and-regulating-orders [Accessed 26th November 2024].

Di Cintio, A., Niccolini, F., Scipioni, S. and Bulleri, F., 2023. Avoiding “Paper Parks”: A Global Literature Review on Socioeconomic Factors Underpinning the Effectiveness of Marine Protected Areas. *Sustainability*, 15(5), e4464.

Di Franco, A., Hogg, K.E., Calò, A., Bennett, N.J., Sévin-Allouet, M.A., Alaminos, O.E., Lang, M., Koutsoubas, D., Prvan, M., Santarossa, L. and Niccolini, F., 2020. Improving marine protected area governance through collaboration and co-production. *Journal of environmental management*, 269, e10757.

Dinu, I., i Bori, A.M., Gràcia, V., García-León, M., Lin-Ye, J., Stănică, A. and Sánchez-Arcilla, A., 2023. Assessing the coastal protection role of seagrass meadows along a barrier beach, southern Romanian coast. *Journal of Sea Research*, 191, e102329.

Dominguez Almela, V., Croker, A.R. and Stafford, R., 2024. Creating simple predictive models in ecology, conservation and environmental policy based on Bayesian belief networks. *PLoS One*, 19(12), e0305882.

Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., Barrett, N.S., Becerro, M.A., Bernard, A.T., Berkhout, J. and Buxton, C.D., 2014. Global conservation outcomes depend on marine protected areas with five key features*. Nature*, 506, 216-220.

Eklöf, J.S., de la Torre Castro, M., Adelsköld, L., Jiddawi, N.S. and Kautsky, N., 2005. Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms. *Estuarine, Coastal and Shelf Science*, 63(3), 385-396.

Feng J.C., Sun, L. and Yan, J., 2023. Carbon sequestration via shellfish farming: A potential negative emissions technology. *Renewable and Sustainable Energy Reviews*, 171, 385-396.

Fidler, R.Y., Ahmadia, G.N., Amkieltiela, Awaludinnoer, Cox, C., Estradivari, Glew, L., Handayani, C., Mahajan, S.L., Mascia, M.B. and Pakiding, F., 2022. Participation, not penalties: Community involvement and equitable governance contribute to more effective multiuse protected areas. *Science Advances*, 8(18), e8929.

Firdausy, C. and Tisdell, C., 1991. Economic Returns from Farming Different types of Seaweed (Eucheuma) and for Farms of Different Sizes in Nusa Penida, Bali, Indonesia. *Research in Agriculture & Applied Economics*, 27.

Fisher, B. and Christopher, T., 2007. Poverty and biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. *Ecological economics*, 62(1), 93-101.

Food and Agriculture Organization of the United Nations, 2024. *The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action*. Rome: Food and Agriculture Organization of the United Nations.

Friess, D.A., Howard, J., Huxham, M., Macreadie, P.I. and Ross, F., 2022. Capitalizing on the global financial interest in blue carbon. *PLoS Climate*, 1(8), e0000061.

Froese, R., Branch, T.A., Proelß, A., Quaas, M., Sainsbury, K. and Zimmermann, C., 2011. Generic harvest control rules for European fisheries. *Fish and fisheries*, 12(3), 340-351.

Froese, R., Stern-Pirlot, A., Winker, H. and Gascuel, D., 2008. Size matters: how single-species management can contribute to ecosystem-based fisheries management. *Fisheries Research*, 92(2-3), 231-241.

García-Buades, M.E., García-Sastre, M.A. and Alemany-Hormaeche, M., 2022. Effects of overtourism, local government, and tourist behavior on residents' perceptions in Alcúdia (Majorca, Spain). *Journal of outdoor recreation and tourism*, 39, e100499.

Gerungan, A. and Chia, K.W., 2020. Scuba diving operators' perspective of scuba diving tourism business in Nusa Penida, Indonesia. *Journal of Outdoor Recreation and Tourism*, 31, e100328.

Gill, D.A., Cheng, S.H., Glew, L., Aigner, E., Bennett, N.J. and Mascia, M.B., 2019. Social synergies, tradeoffs, and equity in marine conservation impacts. *Annual Review of Environment and Resources,* 44, 347-372.

Ginantra, I.K. and Sundra, I.K., 2023. Mollusks diversity to support mangrove tourism attractions in the mangrove forest of Nusa Lembongan, Bali, Indonesia. *International Journal of Science and Research Archive*, 10(2), 578-589.

González-Pérez, J.M., 2020. The dispute over tourist cities. Tourism gentrification in the historic Centre of Palma (Majorca, Spain). *Tourism Geographies*, 22(1), 171-191.

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H. and Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. *Environmental Research Letters*, 7(2), e024006.

Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B., Pike, E.P., Kingston, N., Laffoley, D., Sala, E., Claudet, J. and Friedlander, A.M., 2021. The MPA Guide: A framework to achieve global goals for the ocean. *Science*, 373. e0861.

Guannel, G., Arkema, K., Ruggiero, P. and Verutes, G., 2016. The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. *PloS one*, 11(7), e0158094.

Habib, N., Ariyawardana, A. and Aziz, A.A., 2023. The influence and impact of livelihood capitals on livelihood diversification strategies in developing countries: a systematic literature review. *Environmental Science and Pollution Research*, 30, 69882-69898.

Harris, D.L., Rovere, A., Casella, E., Power, H., Canavesio, R., Collin, A., Pomeroy, A., Webster, J.M. and Parravicini, V., 2018. Coral reef structural complexity provides important coastal protection from waves under rising sea levels. *Science advances*, 4(2), e4350.

Hayes, C.T., Baumbach, D.S., Juma, D. and Dunbar, S.G., 2017. Impacts of recreational diving on hawksbill sea turtle (Eretmochelys imbricata) behaviour in a marine protected area. *Journal of Sustainable Tourism*, 25(1), 79-95. f networks for adaptive management. *Journal of Environmental Management*, 88(4), 79-95.

Hesley, D., Burdeno, D., Drury, C., Schopmeyer, S. and Lirman, D., 2017. Citizen science benefits coral reef restoration activities. *Journal for Nature Conservation*, 40, 94-99.

Hoshino, E., van Putten, I., Girsang, W., Resosudarmo, B.P. and Yamazaki, S., 2016. A Bayesian belief network model for community-based coastal resource management in the Kei Islands, Indonesia. *Ecology and Society*, 21(2).

Hossain, M.S., Sharifuzzaman, S.M., Nobi, M.N., Chowdhury, M.S.N., Sarker, S., Alamgir, M., Uddin, S.A., Chowdhury, S.R., Rahman, M.M., Rahman, M.S. and Sobhan, F., 2021. Seaweeds farming for sustainable development goals and blue economy in Bangladesh. *Marine Policy*, 128, e104469.

Howard, J., McLeod, E., Thomas, S., Eastwood, E., Fox, M., Wenzel, L. and Pidgeon, E., 2017. The potential to integrate blue carbon into MPA design and management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27, 100-115.

Humphreys, J. and Clark, R.W., 2020. A critical history of marine protected areas. *In*: Humphreys, J. and Clark, R.W., eds. *Marine Protected Areas: Science, Policy and Management*. Oxford: Elsevier, 1-12.

Hutchison, J., Spalding, M. and Zu Ermgassen, P., 2014. The role of mangroves in fisheries enhancement. *The Nature Conservancy and Wetlands International*, 54, 434.

Iacarella, J.C., Clyde, G., Bergseth, B.J. and Ban, N.C., 2021. A synthesis of the prevalence and drivers of non-compliance in marine protected areas. *Biological Conservation,* 255, e108992.

Indo Ocean Project, 2024. *Indo Ocean Project Presents at ECRS Europe in Italy.* Bali: Indo Ocean Project. Available from: https://indooceanproject.org/indo-ocean-project-presents-at-ecrs-europe-in-italy/ [accessed 01/01/2025]

Islam, M.S. and Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine pollution bulletin*, 48(7-8), 624-649.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L., 2015. Plastic waste inputs from land into the ocean. *Science*, 347, 768-771.

Jones, A.R., Alleway, H.K., McAfee, D., Reis-Santos, P., Theuerkauf, S.J. and Jones, R.C., 2022. Climate-friendly seafood: The potential for emissions reduction and carbon capture in marine aquaculture. *BioScience*, 72(2), 123-143.

Jones, P.J., 2006. Collective action problems posed by no-take zones. *Marine Policy*, 30(2), 143-156.

Jones, P.J., 2009. Equity, justice and power issues raised by no-take marine protected area proposals. *Marine Policy*, 33(5), 759-765.

Jones, P.J.S., Qiu, W. and De Santo, E.M., 2011. *Governing marine protected areas: getting the balance right*, *Technical Report*. Nairobi-Kenya: United Nations Environment Programme (UNEP).

Jones, P.J., Qiu, W. and De Santo, E.M., 2013. Governing marine protected areas: social–ecological resilience through institutional diversity. *Marine Policy*, 41, 5-13.

Jones, P.J., Stafford, R., Hesse, I. and Khuu, D.T., 2024. Incentive diversity is key to the more effective and equitable governance of marine protected areas. *Frontiers in Marine Science*, 11, 1412654.

Kaiser, M.J., Collie, J.S., Hall, S.J., Jennings, S. and Poiner, I.R., 2003. Impacts of fishing gear on marine benthic habitats. *Responsible fisheries in the marine ecosystem*, 57, 197-216.

Kaiser, M.J., Hormbrey, S., Booth, J.R., Hinz, H. and Hiddink, J.G., 2018. Recovery linked to life history of sessile epifauna following exclusion of towed mobile fishing gear. *Journal of Applied Ecology*, 55(3), 1060-1070.

Kelly, E.L., Cannon, A.L. and Smith, J.E., 2020. Environmental impacts and implications of tropical carrageenophyte seaweed farming. *Conservation Biology*, 34(2), 326-337.

Kimbu, A.N., Booyens, I. and Winchenbach, A., 2022. Livelihood diversification through tourism: identity, well-being, and potential in rural coastal communities. *Tourism review international*, 26(1), 25-40.

Kirkbride-Smith, A.E., Wheeler, P.M. and Johnson, M.L., 2016. Artificial reefs and marine protected areas: a study in willingness to pay to access Folkestone Marine Reserve, Barbados, West Indies. *PeerJ*, 4, e2175.

Krause, G., Le Vay, L., Buck, B.H., Costa-Pierce, B.A., Dewhurst, T., Heasman, K.G., Nevejan, N., Nielsen, P., Nielsen, K.N., Park, K. and Schupp, M.F., 2022. Prospects

of low trophic marine aquaculture contributing to food security in a net zero-carbon world. *Frontiers in Sustainable Food Systems*, 6, e875509.

Laë, R., 1997. Does overfishing lead to a decrease in catches and yields? An example of two West African coastal lagoons. *Fisheries Management and Ecology*, 4(2), 149-164.

Landuyt, D., Broekx, S., D'hondt, R., Engelen, G., Aertsens, J. and Goethals, P.L., 2013. A review of Bayesian belief networks in ecosystem service modelling. *Environmental Modelling & Software*, 46.

Landuyt, D., Broekx, S. and Goethals, P.L., 2016. Bayesian belief networks to analyse trade-offs among ecosystem services at the regional scale. *Ecological Indicators*, 71, 327-335.

Larson, S., Stoeckl, N., Fachry, M.E., Mustafa, M.D., Lapong, I., Purnomo, A.H., Rimmer, M.A. and Paul, N.A., 2021. Women's well-being and household benefits from seaweed farming in Indonesia. *Aquaculture*, 530, e735711.

Leenhardt, P., Low, N., Pascal, N., Micheli, F. and Claudet, J., 2015. The role of marine protected areas in providing ecosystem services. *In:* Belgrano, A., Woodward, G. and Jacob, U., eds. *Aquatic functional biodiversity.* Amsterdam: Academic Press, 211-239.

Lehmann, J.F. and Rungby, A., 2017. Perspectives on Paradise: Reconsidering the Development of Tourism in Southeast Asia through the Case of Nusa Lembongan, Indonesia. *Asia in Focus: A Nordic journal on Asia by early career researchers*, 4, 18-25.

Lester, S.E., Halpern, B.S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B.I., Gaines, S.D., Airamé, S. and Warner, R.R., 2009. Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series*, 384, 33-46.

Lewison, R.L., Crowder, L.B., Wallace, B.P., Moore, J.E., Cox, T., Zydelis, R., McDonald, S., DiMatteo, A., Dunn, D.C., Kot, C.Y. and Bjorkland, R., 2014. Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. *Proceedings of the National Academy of Sciences*, 111(14), 5271-5276.

Lin, B.B. and Dushoff, J., 2004. Mangrove filtration of anthropogenic nutrients in the Rio Coco Solo, Panama. *Management of Environmental Quality: An International Journal*, 15(2), 131-142.

Liu, J., Zapfe, G., Shao, K.-T., Leis, J.L., Matsuura, K., Hardy, G., Liu, M., Robertson, R. and Tyler, J. 2015. *Ocean Sunfish.* Cambridge: The IUCN Red List of Threatened Species. Available from: www.iucnredlist.org/species/190422/97667070 [Accessed on 28 October 2024]

Lovelock, C.E., Barbier, E. and Duarte, C.M., 2022. Tackling the mangrove restoration challenge. *PLoS biology*, 20(10), 3001836.

Lyme Bay Fisheries and Conservation Reserve, 2021. *Voluntary Code of Conduct.* London: Blue Marine Foundation.

Lyme Bay Fisheries and Conservation Reserve, 2025a. *Lyme Bay Fisheries and Conservation Reserve.* London: Blue Marine Foundation. Available from: lymebayreserve.co.uk [Accessed 15 January 2025].

Lyme Bay Fisheries and Conservation Reserve, 2025b. *Voluntary Code of Conduct for the recreational sea angler.* London: Blue Marine Foundation.

Macusi, E.D., Estor, D.E.P., Borazon, E.Q., Clapano, M.B. and Santos, M.D., 2022. Environmental and socioeconomic impacts of shrimp farming in the Philippines: A critical analysis using PRISMA. *Sustainability*, *14*(5), 2977.

Maggs, J.Q., Mann, B.Q. and Cowley, P.D., 2013. Contribution of a large no-take zone to the management of vulnerable reef fishes in the South-West Indian Ocean. *Fisheries research*, 144, 38-47.

Mancha-Cisneros, M.D, Suárez-Castillo, A.N., Torre, J., Anderies, J.M. and Gerber, L.R., 2018. The role of stakeholder perceptions and institutions for marine reserve efficacy in the Midriff Islands Region, Gulf of California, Mexico. *Ocean & Coastal Management*, 162, 181-192.

Mangi, S.C., Rodwell, L.D. and Hattam, C., 2011. Assessing the impacts of establishing MPAs on fishermen and fish merchants: the case of Lyme Bay, UK. *Ambio*, 40, 457-468.

Marine Management Organisation 2024, *Achieving good environmental status through the conservation and restoration of the marine environment.* UK: GOV.UK. Available from: www.gov.uk/government/publications/fisheries-and-seafood-scheme-guidance/achieving-good-environmental-status-through-the-conservation-and-restoration-of-the-marine-environment [accessed 26th November 2024].

Mascorda Cabre, L., Hosegood, P., Attrill, M.J., Bridger, D. and Sheehan, E.V., 2021. Offshore longline mussel farms: a review of oceanographic and ecological interactions to inform future research needs, policy and management. *Reviews in Aquaculture*, 13(4), 1864-1887.

Mascorda-Cabre, L., Hosegood, P., Attrill, M.J. and Sheehan, E.V., 2024a. Biogenic reef creation and biodiversity enhancement by an offshore longline mussel farm. *Ecological Indicators*, 167, e112708.

Mascorda-Cabre, L., Hosegood, P., Attrill, M.J. and Sheehan, E.V., 2024b. Assessing Benthic Recovery Below the United Kingdom's First Large-Scale, Offshore, Longline Mussel Farm. *Aquaculture Research*, 2024(1), 1393014.

Mason, F., 2002. The Newfoundland cod stock collapse: a review and analysis of social factors. *Electronic Green Journal*, 1(17).

Mast, A., Gill, D., Ahmadia, G.N., Darling, E.S., Andradi-Brown, D.A., Geldman, J., Epstein, G. and MacNeil, M.A., 2025. Shared governance increases marine protected area effectiveness. *PloS one*, 20(1), 0315896.

Mosaic 2021. *Area profile for Lyme Regis.* Dorset: Dorset Council. Available from: https://gi.dorsetcouncil.gov.uk/insights/AreaProfiles/Town/lyme-regis#inequalities [Accessed 14th February 2025].

Mumby, P.J., Edwards, A.J., Ernesto Arias-González, J., Lindeman, K.C., Blackwell, P.G., Gall, A., Gorczynska, M.I., Harborne, A.R., Pescod, C.L., Renken, H. and CC Wabnitz, C., 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature*, 427(6974), 533-536.

Nanajkar, M., De, K. and Ingole, B., 2019. Coral reef restoration-a way forward to offset the coastal development impacts on Indian coral reefs. *Marine Pollution Bulletin*, 149, 110504.

Nath, P.K. and Behera, B., 2011. A critical review of impact of and adaptation to climate change in developed and developing economies. *Environment, development and sustainability*, 13, 141-162.

Natural England, 2015. *Improvement Programme for England's Natura 2000 Sites (IPENS) Planning for the Future, Site Improvement Plan Lyme Bay and Torbay*. York: Natural England.

Natural England, 2018*. Natural England 2018. European Site Conservation Objectives for Lyme Bay and Torbay Special Area of Conservation Site code: UK0030372.* York: Natural England, 3.

O'Leary, B.C., Winther-Janson, M., Bainbridge, J.M., Aitken, J., Hawkins, J.P. and Roberts, C.M., 2016. Effective coverage targets for ocean protection. *Conservation Letters*, 9(6), 398-404.

Pikesley, S.K., Godley, B.J., Latham, H., Richardson, P.B., Robson, L.M., Solandt, J.L., Trundle, C., Wood, C. and Witt, M.J., 2016. Pink sea fans (Eunicella verrucosa) as indicators of the spatial efficacy of Marine Protected Areas in southwest UK coastal waters. *Marine Policy*, 64, 38-45.

Pogoda, B., Hausen, T., Rothe, M., Bakker, F., Hauser, S., Colsoul, B., Dureuil, M., Krause, J., Heinicke, K., Pusch, C. and Eisenbarth, S., 2023. Come, tell me how you live: Habitat suitability analysis for Ostrea edulis restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *33*(7), 678-695.

Pomeroy, R.S., Watson, L.M., Parks, J.E. and Cid, G.A., 2005. How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected areas*. Ocean & Coastal Management*, 48(7-8), 485-502.

Pope, E.C., Hays, G.C., Thys, T.M., Doyle, T.K., Sims, D.W., Queiroz, N., Hobson, V.J., Kubicek, L. and Houghton, J.D., 2010. The biology and ecology of the ocean sunfish Mola mola: a review of current knowledge and future research perspectives. *Reviews in Fish Biology and Fisheries*, *20*, 471-487.

Putra, I.B.G.K., 2023. Challenges of Seaweed Cultivation in Nusa Penida for Economic, Tourism, and Environmental Sustainability. *Bali Tourism Journal*, 7(3), 47-50.

Ramirez, L.F., 2016. Marine protected areas in Colombia: Advances in conservation and barriers for effective governance. *Ocean & Coastal Management,* 125, 49-62.

Razak, T.B., Boström-Einarsson, L., Alisa, C.A.G., Vida, R.T. and Lamont, T.A., 2022. Coral reef restoration in Indonesia: A review of policies and projects. *Marine Policy,* 137, e104940.

Rees, S.E., Ashley, M., Evans, L., Mangi, S., Rodwell, L., Attrill, M., Langmead, O., Sheehan, E. and Rees, A., 2016. An evaluation framework to determine the impact of the Lyme Bay Fisheries and Conservation Reserve and the activities of the Lyme Bay Consultative Committee on ecosystem services and human wellbeing. *Plymouth: University of Plymouth Open Access Research (PEARL).*

Rees, S.E., Ashley, M., Evans, L., Mangi, S., Sheehan, E.V., Mullier, T., Rees, A. and Attrill, M.J., 2021. An evaluation of the social and economic impact of a Marine Protected Area on commercial fisheries. *Fisheries Research*, 235, e105819.

Renn, C., Rees, S., Rees, A., Davies, B.F., Cartwright, A.Y., Fanshawe, S., Attrill, M.J., Holmes, L.A. and Sheehan, E.V., 2024. Lessons from Lyme Bay (UK) to inform policy, management, and monitoring of Marine Protected Areas. *ICES Journal of Marine Science*, 81(2), 276-292.

Rife, A.N., Erisman, B., Sanchez, A. and Aburto-Oropeza, O. 2013. When good intentions are not enough… Insights on networks of “paper park” marine protected areas. *Conservation letters*, 6(3), 200-212.

Rimmer, M.A., Larson, S., Lapong, I., Purnomo, A.H., Pong-Masak, P.R., Swanepoel, L. and Paul, N.A., 2021. Seaweed aquaculture in Indonesia contributes to social and economic aspects of livelihoods and community wellbeing. *Sustainability*, 13(19), e10946.

Rohe, J.R., Aswani, S., Schlüter, A. and Ferse, S.C., 2017. Multiple drivers of local (non-) compliance in community-based marine resource management: Case studies from the South Pacific. *Frontiers in Marine Science*, 4, 172.

Ruchimat, T., Basuki, R. and Welly, M., 2013. Nusa Penida marine protected area (MPA) Bali-Indonesia: why need to be protected?. *Transylvanian Review of Systematical and Ecological Research*, 15(1), 193.

Ruff, E.O., Gentry, R.R., Clavelle, T., Thomas, L.R. and Lester, S.E., 2019. Governance and mariculture in the Caribbean. *Marine Policy*, 107, e103565.

Santos, G.S., Burgos, D.C., Lira, S.M. and Schwamborn, R., 2015. The impact of trampling on reef Macrobenthos in Northeastern Brazil: how effective are current conservation strategies?. *Environmental Management*, 56, 847-858.

Seatrees, 2025. *Restoring Bali's Coral Reefs.* California: Seatrees. Available from: https://seatrees.org/pages/project-crystal-bay-nusa-penida-bali-indonesia#:~:text=This%20project%20restores%20the%20degraded,can%20survive%20on%20its%20own [Accessed on 04/01/2025].

Sebastian, P., Sparks, L.D., Resolute, P. and Prasetijo, R., 2024. Connecting communities to coral reefs: a socio-ecological perspective on coral restoration programs in a remote marine protected area. *Journal of Coastal Conservation*, 28(2), 39.

Sheehan, E.V., Stevens, T.F., Gall, S.C., Cousens, S.L. and Attrill, M.J., 2013. Recovery of a temperate reef assemblage in a marine protected area following the exclusion of towed demersal fishing. *PloS one*, 8(12), e83883.

Sheehy-Skeffington, J. and Rea, J., 2017. *How poverty affects people's decision-making processes.* United Kingdom: Joseph Rowntree Foundation.

Silva, P., 2006. Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania. *World Bank Policy Research Working Paper,* 3831.

Singer, R. and Jones, P.J., 2021. Lyme Bay marine protected area: a governance analysis. *Marine Policy,* 127, e103201.

Smith, C.S., DeMattia, E.A., Albright, E., Bromberger, A.F., Hayward, O.G., Mackinson, I.J., Mantell, S.A., McAdoo, B.G., McAfee, D., McCollum, A. and Paxton, A.B., 2025. Beyond despair: Leveraging ecosystem restoration for psychosocial resilience*. Proceedings of the National Academy of Sciences*, 122(2), e2307082121.

Sowman, M. and Sunde, J., 2018. Social impacts of marine protected areas in South Africa on coastal fishing communities. *Ocean & coastal management*, 157, 168-179.

Spalding, M., Meliane, I., J. Bennett, N., Dearden, P., G. Patil, P. and D. Brumbaugh, R., 2016. Building towards the marine conservation end-game: consolidating the role of MPAs in future ocean. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 26, 185-199.

Stafford, R., Williams, R.L. and Herbert, R.J., 2015*.* Simple, policy friendly, ecological interaction models from uncertain data and expert opinion*. Ocean & Coastal Management*, 118, 88-96.

Stamp, T., Pittman, S.J., Holmes, L.A., Rees, A., Ciotti, B.J., Thatcher, H., Davies, P., Hall, A., Wells, G., Olczak, A. and Sheehan, E.V., 2024. Restorative function of offshore longline mussel farms with ecological benefits for commercial crustacean species. *Science of the Total Environment*, 951, e174987.

Stelfox, M., Hudgins, J. and Sweet, M., 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs*. Marine pollution bulletin*, 111(1-2), 6-17.

Stewart, R.R. and Possingham, H.P., 2005. Efficiency, costs, and trade-offs in marine reserve system design. *Environmental Modeling & Assessment*, 10, 203-213.

Suggett, D.J., Edwards, M., Cotton, D., Hein, M. and Camp, E.F., 2023. An integrative framework for sustainable coral reef restoration. *One Earth,* 6(6), 666-681.

Suplicy, F.M., 2020. A review of the multiple benefits of mussel farming. *Reviews in Aquaculture,* 12(1), 204-223.

Suwendri, N.M., Mardika, I.M. and Pidada, I.B., 2021. Nusa Penida in The Past and Present: A Study of The Pattern of Socio-Cultural Life From Agriculture to Tourism. *In:* Suwitra, I.M., Suardani, N.M.A, Budiarta, I.W. and Rahim, R., eds. *Proceedings of*

the 3rd Warmadewa Research and Development Seminar WARDS 2020. Denpasar: EAI, p192.

Swara, I.W.Y., Sutrisna, I.K. and Aswitari, L.P., 2018. Socio-Economic and Demographic Characteristics of Poor Household in Nusa Penida Island, Bali, Indonesia. *IOSR Journal of Economics and Finance*, 9(1), 1-10.

Tan, Y.M., Dalby, O., Kendrick, G.A., Statton, J., Sinclair, E.A., Fraser, M.W., Macreadie, P.I., Gillies, C.L., Coleman, R.A., Waycott, M. and van Dijk, K.J., 2020. Seagrass restoration is possible: insights and lessons from Australia and New Zealand. *Frontiers in Marine Science*, 7, 617.

Tano, S., Eggertsen, M., Wikström, S.A., Berkström, C., Buriyo, A.S. and Halling, C., 2016. Tropical seaweed beds are important habitats for mobile invertebrate epifauna. *Estuarine, Coastal and Shelf Science*, 183, 1-12.

The Lyme Bay Designated Area (Fishing Restrictions) Order 2008 SI 2008/1548.

Theuerkauf, S.J., Barrett, L.T., Alleway, H.K., Costa-Pierce, B.A., St. Gelais, A. and Jones, R.C., 2022. Habitat value of bivalve shellfish and seaweed aquaculture for fish and invertebrates: Pathways, synthesis and next steps*. Reviews in Aquaculture*, 14(1), 54-72.

Tranter, S.N., Ahmadia, G.N., Andradi-Brown, D.A., Muenzel, D., Agung, F., Ford, A.K., Habibi, A., Handayani, C.N., Iqbal, M., Krueck, N.C. and Lazuardi, M.E., 2022. The inclusion of fisheries and tourism in marine protected areas to support conservation in Indonesia*. Marine Policy*, 146, e105301.

Turnbull, J.W., Johnston, E.L. and Clark, G.F., 2021. Evaluating the social and ecological effectiveness of partially protected marine areas*. Conservation Biology*, 35(3), 921-932.

Turnbull, J.W., Shah Esmaeili, Y., Clark, G.F., Figueira, W.F., Johnston, E.L. and Ferrari, R., 2018. Key drivers of effectiveness in small marine protected areas. *Biodiversity and Conservation*, 27(9), 2217-2242.

UN Environment Programme World Conservation Monitoring Centre and The International Union for Conservation of Nature, 2024. *Protected Planet Report.* Cambridge: Protected Planet.

Valiela, I. and Cole, M.L., 2002. Comparative evidence that salt marshes and mangroves may protect seagrass meadows from land-derived nitrogen loads. *Ecosystems*, 5, 92-102.

Vandenberg, J., Humphries, A., Garcia-Quijanoa, C., Moore, A., Pollnac, R. and Abdullah, S., 2021. Assessing indicators and limitations of food security objectives in coral reef restoration. *Conservation and Society*, 19(1), 68-79.

Vandeperre, F., Higgins, R.M., Sánchez-Meca, L., Maynou, F., Goñi, R., Martin-Sosa, P., Pérez-Ruzafa, A., Afonso, P., Bertocci, I., Crec'hriou, R. and D'Anna, G., 2011. Effects of no-take area size and age of marine protected areas of fisheries yields: a meta-analytical approach. *Fish and Fisheries*, 12(4), 412-426.

Veron, J.E.N., Devantier, L.M., Turak, E., Green, A.L., Kininmonth, S., Stafford-Smith, M. and Peterson, N., 2009. Delineating the coral triangle. *Galaxea, Journal of Coral Reef Studies*, 11(2), 91-100.

Whitfield, A.K., 2017. The role of seagrass meadows, mangrove forests, salt marshes and reed beds as nursery areas and food sources for fishes in estuaries*. Reviews in Fish Biology and Fisheries*, 27(1), 75-110.

Williams, S.L., Sur, C., Janetski, N., Hollarsmith, J.A., Rapi, S., Barron, L., Heatwole, S.J., Yusuf, A.M., Yusuf, S., Jompa, J. and Mars, F., 2019. Large-scale coral reef rehabilitation after blast fishing in Indonesia. *Restoration ecology,* 27(2), 447-456.

Wilson, J. and Harrison, P., 2005. Post-settlement mortality and growth of newly settled reef corals in a subtropical environment. *Coral Reefs*, 24, 418-421.

Worboys, G. L. and Trzyna 2015. Managing Protected Areas. *In:* Worboys, G.L., Lockwood, M., Kothari, A., Feary, S., Pulsford, I., eds. *Protected Area Governance and Management*, Canberra: ANU Press, 207-205.

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S. and Jensen, O.P., 2009. Rebuilding global fisheries. *Science,* 325(5940), 578-585.

Yunitawati, D. and Clifton, J., 2021. Governance in the early stages of marine protected area development: A case study of Nusa Penida District Marine Conservation Area, Indonesia. *Marine Policy,* 127, e103653.

Zhu, L., Huguenard, K., Zou, Q.P., Fredriksson, D.W. and Xie, D., 2020. Aquaculture farms as nature-based coastal protection: Random wave attenuation by suspended and submerged canopies. *Coastal Engineering*, 160, e103737.

Zupan, M., Bulleri, F., Evans, J., Fraschetti, S., Guidetti, P., Garcia-Rubies, A., Sostres, M., Asnaghi, V., Caro, A., Deudero, S. and Goñi, R., 2018. How good is your marine protected area at curbing threats?. *Biological Conservation*, 221, 237-245.

Appendix 1.

Nusa Penida BBN scores and justifications

Table 1. BBN scores given for the influence of seagrass on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Seagrass	Seagrass	0	No direct relationship. Source: opinion
Seagrass	Mangroves	0	No direct relationship. Seagrass dissipates waves, protecting mangroves, but direct relationship is between seagrass and coastal protection nodes. Source: Fortes (1988) https://www.jstor.org/stable/4313455; Guannel et al. (2016) https://doi.org/10.1371/journal.pone.0158094
Seagrass	Coral Reef	0	No direct relationship. Source: opinion
Seagrass	Zooplankton	0	Zooplankton can be more abundant in seagrass, but the direct relationship is between increased phytoplankton and water quality in seagrass meadows. Source: Ambo-Rappe (2016) DOI: 10.3923/jest.2016.246.256; Deepika et al. (2019) https://doi.org/10.20546/ijcmas.2019.807.244; Lo et al. (2020) https://doi.org/10.51200/bjomsa.v4i1.1747
Seagrass	Invertebrates	3	Provides habitat and food resource for invertebrates. Studies found seagrass to hold 3 times the number of invertebrates than nearby bare ground. Source: Virnstein et al. (1983) https://www.jstor.org/stable/24320346; Cummins et al. (2004) https://doi.org/10.1071/MF04017; Bloomfield and Gillanders (2005)

			https://doi.org/10.1007/BF02732754; Ambo-Rappe (2016) DOI: 10.3923/jest.2016.246.256
Seagrass	Fish	2	Provides nursery ground/shelter from predators, however, invertebrates play a part in attracting fish to this habitat, and this relationship has its own edge score. Source: Ambo-Rappe et al. (2013) http://dx.doi.org/10.4236/oje.2013.35038; Ambo-Rappe (2016) DOI: 10.3923/jest.2016.246.256; Susilo et al. (2018) https://doi.org/10.1088/1755-1315/116/1/012058; Simanjuntak et al. (2020) https://doi.org/10.1088/1755-1315/404/1/012063
Seagrass	Manta Rays	0	No evidence to suggest that manta rays use seagrass habitats. Source: opinion
Seagrass	Sunfish	0	No evidence to suggest that sunfish interact with seagrass. They are described as pelagic deep-sea fish. Source: Potter and Howell (2011) https://doi.org/10.1016/j.jembe.2010.10.014
Seagrass	Water quality	1	Seagrass meadows shown to reduce suspended particles and nutrients, pathogens and stabilise temperature. However, not every aspect of pollution is reduced by this habitat. Source: Lamb et al. (2017) DOI:10.1126/science.aal1956
Seagrass	Biodiversity	4	The presence of 8 seagrass species directly contributes to biodiversity. Source: Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Seagrass	Selective fishing	0	No direct relationship. Source: opinion
Seagrass	Boat use	0	No direct relationship. Source: opinion
Seagrass	Anchoring	0	No direct relationship. Source: opinion
Seagrass	Disturbance	0	No direct relationship. Source: opinion
Seagrass	Recreation	0	No direct relationship. Source: opinion
Seagrass	Tourism	0	No direct relationship. Source: opinion
Seagrass	Seaweed farming	0	No direct relationship. Source: opinion
Seagrass	Coastal development	0	No direct relationship. Source: opinion
Seagrass	Coastal protection	2	Seagrass creates wave attenuation, however, levels of protection depend on aspects such as meadow size and seagrass species. Fortes (1988) https://www.jstor.org/stable/4313455; Guannel et al. (2016) https://doi.org/10.1371/journal.pone.0158094
Seagrass	Fishing employment	0	No direct relationship. Source: opinion

Seagrass	Tourism employment	0	No direct relationship. Source: opinion
Seagrass	Aquaculture employment	0	No direct relationship. Source: opinion
Seagrass	Cultural heritage	0	No direct relationship. Source: opinion
Seagrass	Community acceptance	0	No direct relationship. Source: opinion

Table 2. BBN scores given for the influence of mangroves on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Mangroves	Seagrass	0	No direct relationship. Source: Fortes (1988) https://www.jstor.org/stable/4313455; Valiela and Cole (2002); https://doi.org/10.1007/s10021-001-0058-4; Mishra and Apte (2020) https://doi.org/10.3354/meps13349; Dahl et al. (2022) https://doi.org/10.1016/j.marenvres.2022.105608
Mangroves	Mangroves	0	No direct relationship. Source: opinion
Mangroves	Coral Reef	0	No direct relationship. Source: opinion
Mangroves	Zooplankton	0	Some species more abundant in mangroves, some species more abundant outside of mangroves, meaning no direct relationship. Source: Granek and Frasier (2007) https://repository.si.edu/handle/10088/18705
Mangroves	Invertebrates	3	Provides habitat, shelter, and food for invertebrates. Source: Nagelkerken et al. (2008) https://doi.org/10.1016/j.aquabot.2007.12.007; Corte et al. (2021) https://doi.org/10.1007/s10531-021-02158-y; Damastuti et al. (2022) https://doi.org/10.1016/j.tfp.2022.100202; Ginantra & Sunda (2023) https://doi.org/10.30574/ijsra.2023.10.2.0978
Mangroves	Fish	3	Provides nursery and shelter for some juvenile fish. Some of the habitat use is caused by invertebrates, and accounted for in the invertebrate-fish edge score. Source: Mumby et al. (2004) https://doi.org/10.1038/nature02286; Nagelkerken et al. (2008) https://doi.org/10.1016/j.aquabot.2007.12.007; Unsworth et al. (2008) https://doi.org/10.3354/meps07199; Nanjo et al. (2014) https://doi.org/10.1016/j.jembe.2014.08.014; Whitfield (2017) https://doi.org/10.1007/s11160-016-9454-x
Mangroves	Manta Rays	0	No direct relationship. Source: opinion

Mangroves	Sunfish	0	No evidence of sunfish interacting with mangroves. Reported as pelagic deep-sea species. Source: Potter and Howell (2011) https://doi.org/10.1016/j.jembe.2010.10.014
Mangroves	Water quality	3	Mangrove root systems filter nitrates, phosphates, and other pollutants. Source: Valiela and Cole (2002) https://doi.org/10.1007/s10021-001-0058-4; Lin and Dushoff (2004) https://doi.org/10.1108/14777830410523071
Mangroves	Biodiversity	4	The presence of 13 mangrove species in Nusa Penida directly contribute to biodiversity. Source: Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Mangroves	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Mangroves	Selective fishing	0	No direct relationship. Source: opinion
Mangroves	Boat use	0	No direct relationship. Source: opinion
Mangroves	Anchoring	0	No direct relationship. Source: opinion
Mangroves	Disturbance	0	No direct relationship. Source: opinion
Mangroves	Recreation	0	No direct relationship. Mangrove tours are a popular tourist activity, however this is accounted for in the mangroves-tourism edge score. Source: Ginantra and Sundra (2023) https://doi.org/10.30574/ijsra.2023.10.2.0978
Mangroves	Tourism	1	Mangrove tours are a popular tourist activity and therefore mangroves have some impact on tourism, however, the main drivers of tourism are manta ray seeing and SCUBA diving. Source: Ginantra and Sundra (2023) https://doi.org/10.30574/ijsra.2023.10.2.0978
Mangroves	Seaweed farming	0	No direct relationship. Source: opinion
Mangroves	Coastal development	0	No direct relationship. Source: opinion
Mangroves	Coastal protection	3	Increased mangrove cover protects land due to wave dissipation. Enough cover can reduce tsunami impact by 50%. Source: Vipriyanti et al. (2024) https://doi.org/10.1007/s10668-022-02721-9
Mangroves	Fishing employment	0	No direct relationship. Source: opinion

Mangroves	Tourism employment	0	No direct relationship. Source: opinion
Mangroves	Aquaculture employment	0	No direct relationship. Source: opinion
Mangroves	Cultural heritage	1	Mangroves shape the landscape which contributes to sense of place and community identity. Source: opinion
Mangroves	Community acceptance	1	Conserving a valued landscape and ecosystem is likely to be supported. Support for benefits from mangroves to fishing and other ecosystem services are accounted for in these specific edge scores. Source: opinion

Table 3. BBN scores given for the influence of coral reefs on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Coral Reef	Seagrass	0	No direct relationship. Source: opinion
Coral Reef	Mangroves	0	No direct relationship. Source: opinion
Coral Reef	Coral Reef	0	No direct relationship. Source: opinion
Coral Reef	Zooplankton	-1	Some corals eat zooplankton. Source: Santoso et al. (2022) https://doi.org/10.1007/s10641-021-01198-1
Coral Reef	Invertebrates	3	Many invertebrates (but not all) have dependence or symbiosis with particular corals. Reefs provide physical habitat/shelter for others. Source: Gibson et al. (2011) https://www.researchgate.net/publication/230604775
Coral Reef	Fish	3	Provides nursery habitat for juvenile fish and provides food. Source: Santoso et al. (2022) https://doi.org/10.1007/s10641-021-01198-1
Coral Reef	Manta Rays	1	Provides a habitat used by manta rays to use as a cleaning station and nursery ground and may be some element of shelter provision. However, attraction to the reef is primarily accounted for in the fish-manta ray edge score (cleaner fish), and zooplankton-manta ray edge score (as aggregation in this habitat is largely due to abundance of zooplankton). Source: Jaine et al. (2012) https://doi.org/10.1371/journal.pone.0046170; Stewart et al. (2018) https://doi.org/10.3389/fmars.2018.00314; Setyawan et al. (2022) https://doi.org/10.3389/fmars.2022.815094

Coral Reef	Sunfish	0	No evidence of direct relationship. Sunfish attracted to the reef by cleaner fish, and this is accounted for in the fish-sunfish edge score. Source: Konow et al. (2006) https://doi.org/10.1007/s00338-006-0086-9
Coral Reef	Water quality	2	Many corals and sponges filter pollutant particles. Source: UNEP (2024). Available from: https://www.unep.org/news-and-stories/story/seven-ways-youre-connected-coral-reefs#:~:text=Coral%20reefs%20help%20keep%20our,in%20water)%20in%20the%20water accessed on 01/08/2024.
Coral Reef	Biodiversity	4	296 coral species in Nusa Penida, which directly contribution to biodiversity. Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Coral Reef	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Coral Reef	Selective fishing	0	No direct relationship. Source: opinion
Coral Reef	Boat use	0	No direct relationship. Source: opinion
Coral Reef	Anchoring	0	No direct relationship. Source: opinion
Coral Reef	Disturbance	0	No direct relationship. Source: opinion
Coral Reef	Recreation	0	No direct relationship. Source: opinion
Coral Reef	Tourism	2	A lot of tourism in Nusa Penida is driven SCUBA diving opportunities, where healthy, diverse coral reefs are likely valued. Source: opinion
Coral Reef	Seaweed farming	0	No direct relationship. Source: opinion
Coral Reef	Coastal development	0	No direct relationship. Source: opinion
Coral Reef	Coastal protection	3	Reefs dissipate waves and structural complexity creates more protection. Source: Harris et al. (2018) https://doi.org/10.1126/sciadv.aao4350
Coral Reef	Fishing employment	0	No direct relationship. Source: opinion
Coral Reef	Tourism employment	0	No direct relationship. Source: opinion
Coral Reef	Aquaculture employment	0	No direct relationship. Source: opinion
Coral Reef	Cultural heritage	1	A landscape that contributes to sense of place. There can also be spiritual believes connected to the reefs, and traditional practices that take place in this area. Source: opinion
Coral Reef	Community acceptance	1	Conserving a valued landscape and ecosystem is likely to be supported. Support for benefits from reefs for fishing and other ecosystem services are accounted for in those specific edge scores. Source: opinion

Table 4. BBN scores given for the influence of zooplankton on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Zooplankton	Seagrass	0	No evidence found of zooplankton directly impacting seagrass. Source: opinion
Zooplankton	Mangroves	0	No direct relationship. Source: opinion
Zooplankton	Coral Reef	1	Some corals eat zooplankton. Source: Santoso et al. (2022) https://doi.org/10.1007/s10641-021-01198-1
Zooplankton	Zooplankton	0	No direct relationship. Source: opinion
Zooplankton	Invertebrates	2	Some invertebrates such as jellyfish, bivalves and crabs eat zooplankton. Source: Opinion; Purcell (2003); https://doi.org/10.3354/meps246137; Daewell et al. 2013 https://doi.org/10.1093/icesjms/fst125
Zooplankton	Fish	3	Zooplankton is an important food resource for secondary consumers. Source: Ambo-Rappe (2016) DOI: 10.3923/jest.2016.246.256
Zooplankton	Manta Rays	3	Zooplankton are a primary food resource for manta rays. Source: Armstrong et al. (2016) https://doi.org/10.1371/journal.pone.0153393; Germanov et al. (2019) https://doi.org/10.3389/fmars.2019.00215; Armstrong et al. (2021) https://doi.org/10.7717/peerj.11992
Zooplankton	Sunfish	2	Zooplankton forms a considerable part of sunfish diet, however sunfish also eat many invertebrates and some fish. Source: Sousa et al. (2016) https://doi.org/10.1186/s40317-016-0099-2; Tito and Susilo (2017) https://doi.org/10.1088/1755-1315/55/1/012031; Nyegaard et al. (2023) https://doi.org/10.3354/meps14436
Zooplankton	Water quality	1	Zooplankton prey on phytoplankton, reducing harmful algae blooms, however this is just one aspect of water quality. Source: Turner and Granéli (2006) https://doi.org/10.1007/978-3-540-32210-8_27
Zooplankton	Biodiversity	4	Presence of zooplankton species contribute directly to overall biodiversity. Source: opinion
Zooplankton	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Zooplankton	Selective fishing	0	No direct relationship. Source: opinion
Zooplankton	Boat use	0	No direct relationship. Source: opinion
Zooplankton	Anchoring	0	No direct relationship. Source: opinion

Zooplankton	Disturbance	0	No direct relationship. Source: opinion
Zooplankton	Recreation	0	No direct relationship. Source: opinion
Zooplankton	Tourism	0	No direct relationship. Source: opinion
Zooplankton	Seaweed farming	0	No direct relationship. Source: opinion
Zooplankton	Coastal development	0	No direct relationship. Source: opinion
Zooplankton	Coastal protection	0	No direct relationship. Source: opinion
Zooplankton	Fishing employment	0	No direct relationship. Source: opinion
Zooplankton	Tourism employment	0	No direct relationship. Source: opinion
Zooplankton	Aquaculture employment	0	No direct relationship. Source: opinion
Zooplankton	Cultural heritage	0	No direct relationship. Source: opinion
Zooplankton	Community acceptance	0	No direct relationship. Source: opinion

Table 5. BBN scores given for the influence of invertebrates on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Invertebrates	Seagrass	1	Symbiotic relationships exist between some invertebrates. For example, bivalves absorb sulphide to keep levels tolerable for seagrass. Source: Lewis and Anderson (2012) https://doi.org/10.1890/12-0038.1
Invertebrates	Mangroves	1	Burrowing crabs and bivalves help mangroves with nutrient cycling. Seedling predation helps with mangrove biodiversity. Source: Kristensen (2008) https://doi.org/10.1016/j.seares.2007.05.004; Nagelkerken et al. (2008) https://doi.org/10.1016/j.aquabot.2007.12.007; Damastuti et al. (2022) https://doi.org/10.1016/j.tfp.2022.100202; Ginantra and Sundra (2023) https://doi.org/10.30574/ijsra.2023.10.2.0978
Invertebrates	Coral Reef	2	Some invertebrates graze algae, allowing coral to grow. Some coral eat some invertebrate. However, some invertebrates eat coral and spread disease. Source: Gibson et al. (2011) https://www.researchgate.net/publication/230604775; Nicolet et al. (2013) https://doi.org/10.1007/s00338-013-1010-8; Francis et al. (2019) https://doi.org/10.1016/j.gecco.2019.e00593

Invertebrates	Zooplankton	-1	Some invertebrates such as jellyfish, bivalves and crabs eat zooplankton. Source: Opinion; Purcell (2003); https://doi.org/10.3354/meps246137; Daewell et al. 2013 https://doi.org/10.1093/icesjms/fst125
Invertebrates	Invertebrates	0	No direct relationship. Source: opinion
Invertebrates	Fish	3	Invertebrates are the main food resource for many fish. Source: Nagelkerken et al. (2008) https://doi.org/10.1016/j.aquabot.2007.12.007; Lewis and Anderson (2012) https://doi.org/10.1890/12-0038.1
Invertebrates	Manta Rays	0	Zooplankton are the main food resource for Manta Ray, with no mention of invertebrates in literature. Source: Armstrong et al. (2021) https://doi.org/10.7717/peerj.11992
Invertebrates	Sunfish	2	Juvenile sunfish may eat crustaceans, jellies, squids etc, and switch to gelenatous zooplankton when reaching adulthood. Source: Oceansunfish.org. Available from: https://oceansunfish.org/diet-size-and-growth/. Accessed 24th July 2024.
Invertebrates	Water quality	1	Some invertebrates filter sediment. Source: opinion
Invertebrates	Biodiversity	4	Invertebrate species directly contribute to biodiversity. Source: opinion
Invertebrates	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Invertebrates	Selective fishing	0	No direct relationship. Source: opinion
Invertebrates	Boat use	0	No direct relationship. Source: opinion
Invertebrates	Anchoring	0	No direct relationship. Source: opinion
Invertebrates	Disturbance	0	No direct relationship. Source: opinion
Invertebrates	Recreation	0	No direct relationship. Source: opinion
Invertebrates	Tourism	0	No direct relationship. Source: opinion
Invertebrates	Seaweed farming	-1	Herbivorous invertebrates, such as crustaceans and sea urchins graze on seaweed and cause some loss. Nicotri (1977) https://doi.org/10.1016/0044-8486(77)90179-X; Ganesan et al. (2006) https://www.jstor.org/stable/24094109
Invertebrates	Coastal development	0	No direct relationship. Source: opinion
Invertebrates	Coastal protection	0	No direct relationship. Source: opinion
Invertebrates	Fishing employment	0	No direct relationship. Source: opinion

Invertebrates	Tourism employment	0	No direct relationship. Source: opinion
Invertebrates	Aquaculture employment	0	No direct relationship. Source: opinion
Invertebrates	Cultural heritage	0	No direct relationship. Source: opinion
Invertebrates	Community acceptance	0	No direct relationship. Source: opinion

Table 6. BBN scores given for the influence of fish on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Fish	Seagrass	0	Herbivorous fish , such as parrot fish, graze on seagrass, they also nutrient cycle providing nutrients for seagrass to grow, so potentially neutral overall relationship. Source: Kirsch et al. (2002) https://doi.org/10.3354/meps227071: Dunne et al. (2023) https://doi.org/10.1016/j.marenvres.2023.105884
Fish	Mangroves	0	No evidence of fish benefiting mangroves found in literature. Source: opinion
Fish	Coral Reef	2	Reef fish such as parrotfish eat algae from reef, reducing competition and allowing coral to grow. They excrete nutrients to the area for coral to grow. Not all fish will have this benefit. Source: NOAA Fisheries (2022). Available from: https://www.fisheries.noaa.gov/feature-story/how-are-fisheries-and-coral-reefs-connected. Accessed 24th July 2024
Fish	Zooplankton	-3	Zooplankton are the main food source for many small fish. Source: Ambo-Rappe (2016) DOI: 10.3923/jest.2016.246.256; Capuzzo et al. (2018) https://doi.org/10.1111/gcb.13916; Lomartie et al. (2021) https://doi.org/10.1016/j.ecolind.2021.107867; Santoso et al. (2022) https://doi.org/10.1007/s10641-021-01198-1
Fish	Invertebrates	-3	Invertebrates are the main food source for many small fish. Source: Lewis and Anderson (2012) https://doi.org/10.1890/12-0038.1
Fish	Fish	0	No direct relationship. Source: opinion
Fish	Manta Rays	0	Manta Rays main food resource is zooplankton. Source: Barr and Abelson (2019) https://doi.org/10.3389/fmars.2019.00088; Venables et al. (2020) https://doi.org/10.3354/meps13178; Armstrong et al. (2021) https://doi.org/10.7717/peerj.11992
Fish	Sunfish	1	Sunfish are reported to eat some fish. Source: Pope et al. (2010) https://doi.org/10.1007/s11160-009-9155-9; Sousa et al. (2016) https://doi.org/10.1186/s40317-016-0099-2; Nakamura and Sato (2014) https://doi.org/10.1007/s00227-014-2416-8

Fish	Water quality	0	No papers found on how fish may increase water quality. Source: opinion
Fish	Biodiversity	4	296 reef fish species in Nusa Penida, contributing to biodiversity. Source: Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Fish	Pelagic non-selective fishing	4	Increased fish increases fishing and catch opportunities. Source: opinion
Fish	Selective fishing	4	Increased fish increases fishing and catch opportunities. Source: opinion
Fish	Boat use	0	No direct relationship. Source: opinion
Fish	Anchoring	0	No direct relationship. Source: opinion
Fish	Disturbance	0	No direct relationship. Source: opinion
Fish	Recreation	0	No direct relationship. Source: opinion
Fish	Tourism	2	Tropical fish are part of the attraction of diving, which is one of the main drivers of tourism in this MPA. Source: opinion
Fish	Seaweed farming	-1	Herbivorous fish graze on seaweed causing small loss. Source: Ganesan et al. (2006) https://www.jstor.org/stable/24094109
Fish	Coastal development	0	No direct relationship. Source: opinion
Fish	Coastal protection	0	No direct relationship. Source: opinion
Fish	Fishing employment	0	No direct relationship. Source: opinion
Fish	Tourism employment	0	No direct relationship. Source: opinion
Fish	Aquaculture employment	0	No direct relationship. Source: opinion
Fish	Cultural heritage	1	Fish can contribute to cultural heritage through symbolism, mythology, and their value in historic fishing practices. Source: opinion. Source: opinion
Fish	Community acceptance	1	As a valued part of the ecosystem, it is likely that conservation of fish would be met with acceptance from community. This is also represented in edge scores between acceptance and fishing opportunities. Source: opinion

Table 7. BBN scores given for the influence of manta rays on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Manta Rays	Seagrass	0	No direct relationship. Source: opinion

Manta Rays	Mangroves	0	No direct relationship. Source: opinion
Manta Rays	Coral Reef	0	No direct relationship. Source: opinion
Manta Rays	Zooplankton	-3	Zooplankton are the main food resource for manta rays. Source: Jaine et al. (2012) https://doi.org/10.1371/journal.pone.0046170; Armstrong et al. (2016) Armstrong et al. (2016) https://doi.org/10.1371/journal.pone.0153393; Germanov et al. (2019) https://doi.org/10.3389/fmars.2019.00215; Armstrong et al. (2021) https://doi.org/10.7717/peerj.11992
Manta Rays	Invertebrates	0	No mention of manta rays consuming invertebrates in literature, primary food is zooplankton. Source: Jaine et al. (2012) https://doi.org/10.1371/journal.pone.0046170; Armstrong et al. (2016) Armstrong et al. (2016) https://doi.org/10.1371/journal.pone.0153393; Germanov et al. (2019) https://doi.org/10.3389/fmars.2019.00215; Armstrong et al. (2021) https://doi.org/10.7717/peerj.11992
Manta Rays	Fish	0	Fish not a regular food resource for manta rays, and although thy use cleaner fish to reduce parasite load, this is considered mutualistic. Source: Rohner et al. (2013) https://doi.org/10.3354/meps10290; : Barr and Abelson (2019) https://doi.org/10.3389/fmars.2019.00088; Venables et al. (2020) https://doi.org/10.3354/meps13178; Armstrong et al. (2021) https://doi.org/10.1002/ece3.7464
Manta Rays	Manta Rays	0	No direct relationship. Source: opinion
Manta Rays	Sunfish	0	No direct relationship. Source: opinion
Manta Rays	Water quality	0	No direct relationship. Source: opinion
Manta Rays	Biodiversity	1	Presence of this manta ray species contributes to species richness, but only by 1 species. Source: opinion
Manta Rays	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Manta Rays	Selective fishing	0	No direct relationship. Source: opinion
Manta Rays	Boat use	0	No direct relationship. Source: opinion
Manta Rays	Anchoring	0	No direct relationship. Source: opinion
Manta Rays	Disturbance	0	No direct relationship. Source: opinion
Manta Rays	Recreation	0	No direct relationship. Source: opinion
Manta Rays	Tourism	3	Main driver of tourism in Nusa Penida is manta ray spotting and diving. Source: Yunitawati and Clifton (2021) https://doi.org/10.1016/j.marpol.2019.103653

Manta Rays	Seaweed farming	0	No direct relationship. Source: opinion
Manta Rays	Coastal development	0	No direct relationship. Source: opinion
Manta Rays	Coastal protection	0	No direct relationship. Source: opinion
Manta Rays	Fishing employment	0	No direct relationship. Source: opinion
Manta Rays	Tourism employment	0	No direct relationship. Source: opinion
Manta Rays	Aquaculture employment	0	No direct relationship. Source: opinion
Manta Rays	Cultural heritage	1	Manta rays likely to have cultural significance as a charismatic species that aggregate in the area. May be a symbolic/spiritual link. Source: opinion
Manta Rays	Community acceptance	1	Community likely to be accepting of the conservation of a valued species in the area. Also accounted for in tourism employment-community acceptance edge, as manta rays are a driver of tourism. Source: opinion

Table 8. BBN scores given for the influence of sunfish on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Sunfish	Seagrass	0	No direct relationship. Source: opinion
Sunfish	Mangroves	0	No direct relationship. Source: opinion
Sunfish	Coral Reef	0	No direct relationship. Source: opinion
Sunfish	Zooplankton	-3	Zooplankton is the main food resource for sunfish. Source: Sims et al. (2009) https://doi.org/10.1371/journal.pone.0007351; Sousa et al. (2016) https://doi.org/10.1186/s40317-016-0099-2; Tito and Susilo (2017) https://doi.org/10.1088/1755-1315/55/1/012031; Nyegaard et al. (2023) https://doi.org/10.3354/meps14436
Sunfish	Invertebrates	-1	Juvenile sunfish may eat crustaceans, jellies, squids etc, and switch to gelenatous zooplankton when reaching adulthood. Source: Oceansunfish.org. available from: https://oceansunfish.org/diet-size-and-growth/. Accessed 24th July 2024.
Sunfish	Fish	-1	Sunfish are reported to eat some fish. Source: Pope et al. (2010) https://doi.org/10.1007/s11160-009-9155-9; Sousa et al. (2016) https://doi.org/10.1186/s40317-016-0099-2; Nakamura and Sato (2014) https://doi.org/10.1007/s00227-014-2416-8

Sunfish	Manta Rays	0	No direct relationship. Source: opinion
Sunfish	Sunfish	0	No direct relationship. Source: opinion
Sunfish	Water quality	0	No direct relationship. Source: opinion
Sunfish	Biodiversity	1	Presence of sunfish contributes to species richness, but only by 1 species. Source: opinion
Sunfish	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Sunfish	Selective fishing	0	No direct relationship. Source: opinion
Sunfish	Boat use	0	No direct relationship. Source: opinion
Sunfish	Anchoring	0	No direct relationship. Source: opinion
Sunfish	Disturbance	0	No direct relationship. Source: opinion
Sunfish	Recreation	0	No direct relationship. Source: opinion
Sunfish	Tourism	2	Sunfish are a tourist attraction, but Manta Ray & general diving reported as the main tourism driver. Source: Yunitawati and Clifton (2021) https://doi.org/10.1016/j.marpol.2019.103653; Nyegaard et al. (2023) https://doi.org/10.3354/meps14436
Sunfish	Seaweed farming	0	No direct relationship. Source: opinion
Sunfish	Coastal development	0	No direct relationship. Source: opinion
Sunfish	Coastal protection	0	No direct relationship. Source: opinion
Sunfish	Fishing employment	0	No direct relationship. Source: opinion
Sunfish	Tourism employment	0	No direct relationship. Source: opinion
Sunfish	Aquaculture employment	0	No direct relationship. Source: opinion
Sunfish	Cultural heritage	1	May hold cultural significance as a charismatic species that aggregate in the area. May be a symbolic/spiritual link. Source: opinion
Sunfish	Community acceptance	0	No direct relationship. Source: opinion

Table 9. BBN scores given for the influence of water quality on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Water quality	Seagrass	3	Excess nutrients create algae blooms, smothering seagrass and stopping it from growing. Source: Breininger et al. (2016). https://doi.org/10.1111/cobi.12791
Water quality	Mangroves	2	Chemical pollution impacts the phenology of mangroves. Source: Celis-Hernandez et al. (2022) https://doi.org/10.1016/j.scitotenv.2021.152309
Water quality	Coral Reef	3	Sediments, nutrients, pathogens, metals and microplastic all damage coral. Algal blooms smother, litter can block sunlight or break coral, sunscreen and pesticides alters phenology. Source: United States Environmental Protection Agency (2025). Available from: https://www.epa.gov/coral-reefs/threats-coral-reefs accessed on 1st Feb 2025.
Water quality	Zooplankton	2	Short life span and rapid rate of reproduction means zooplankton respond more rapidly than fish to pollutants. Source: Boldrocchi et al. (2023). Source: https://doi.org/10.1016/j.marpolbul.2023.115732
Water quality	Invertebrates	1	Assuming effects on invertebrates similar to other organisms. Source: opinion
Water quality	Fish	1	Pollution can make fish ill, or cause oxygen depletion causing dead zones, they can ingest plastic. Source: Bailey et al. (2020) https://doi.org/10.1007/978-981-15-3372-3; Savoca et al. (2021) https://doi.org/10.1111/gcb.15533
Water quality	Manta Rays	1	Manta rays can be negatively affected by entanglement of ghost nets, ingestion of plastic etc. Source: Manta Watch (2022). Available from: https://mantawatchnz.org/threats/#fisher. Accessed on 14th August 2024
Water quality	Sunfish	1	Sunfish can eat plastic in mistake for jellyfish and choke and can get tangled in ghost nets. Source: IUCN (2011). Available from: https://www.iucnredlist.org/species/190422/97667070#threats. Accessed on 14th August 2024
Water quality	Water quality	0	No direct relationship. Source: opinion
Water quality	Biodiversity	0	No direct relationship. Source: opinion
Water quality	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Water quality	Selective fishing	0	No direct relationship. Source: opinion
Water quality	Boat use	0	No direct relationship. Source: opinion
Water quality	Anchoring	0	No direct relationship. Source: opinion
Water quality	Disturbance	0	No direct relationship. Source: opinion

Water quality	Recreation	0	No direct relationship. Source: opinion
Water quality	Tourism	1	Bad water quality and litter could deter tourists over time. Source: opinion
Water quality	Seaweed farming	3	Pollution can kill seaweed crops. Source: opinion
Water quality	Coastal development	0	No direct relationship. Source: opinion
Water quality	Coastal protection	0	No direct relationship. Source: opinion
Water quality	Fishing employment	0	No direct relationship. Source: opinion
Water quality	Tourism employment	0	No direct relationship. Source: opinion
Water quality	Aquaculture employment	0	No direct relationship. Source: opinion
Water quality	Cultural heritage	1	Pollution can impact the condition and accessibility of cultural resources in the marine environment. Source: opinion
Water quality	Community acceptance	1	Community likely to be accepting of improvements to local environment. Source: opinion

Table 10. BBN scores given for the influence of biodiversity on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Biodiversity	Seagrass	0	No direct relationship. Source: opinion
Biodiversity	Mangroves	0	No direct relationship. Source: opinion
Biodiversity	Coral Reef	0	No direct relationship. Source: opinion
Biodiversity	Zooplankton	0	No direct relationship. Source: opinion
Biodiversity	Invertebrates	0	No direct relationship. Source: opinion
Biodiversity	Fish	0	No direct relationship. Source: opinion
Biodiversity	Manta Rays	0	No direct relationship. Source: opinion
Biodiversity	Sunfish	0	No direct relationship. Source: opinion
Biodiversity	Water quality	0	No direct relationship. Source: opinion
Biodiversity	Biodiversity	0	No direct relationship. Source: opinion
Biodiversity	Pelagic non-selective fishing	0	No direct relationship. Source: opinion

Biodiversity	Selective fishing	0	No direct relationship. Source: opinion
Biodiversity	Boat use	0	No direct relationship. Source: opinion
Biodiversity	Anchoring	0	No direct relationship. Source: opinion
Biodiversity	Disturbance	0	No direct relationship. Source: opinion
Biodiversity	Recreation	0	No direct relationship. Source: opinion
Biodiversity	Tourism	3	Diving to is a main tourist attraction. Assumed that better biodiversity would boost this. Source: opinion; Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Biodiversity	Seaweed farming	0	No direct relationship. Source: opinion
Biodiversity	Coastal development	0	No direct relationship. Source: opinion
Biodiversity	Coastal protection	0	No direct relationship. Source: opinion
Biodiversity	Fishing employment	0	No direct relationship. Source: opinion
Biodiversity	Tourism employment	0	No direct relationship. Source: opinion
Biodiversity	Aquaculture employment	0	No direct relationship. Source: opinion
Biodiversity	Cultural heritage	0	No direct relationship. Source: opinion. Already accounted for in more specific ecosystem edge scores. Source: opinion
Biodiversity	Community acceptance	0	No direct relationship. Source: opinion. . Already accounted for in more specific ecosystem edge scores. Source: opinion

Table 11. BBN scores given for the influence of pelagic non-selective fishing on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Pelagic non-selective fishing	Seagrass	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Mangroves	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Coral Reef	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Zooplankton	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Invertebrates	-1	No contact with benthic habitats but could still capture invertebrates from the water column. Source: opinion

Pelagic non-selective fishing	Fish	-4	Fishing removes fish. Source: opinion
Pelagic non-selective fishing	Manta Rays	-2	Mid trawlers/purse sein often catch manta rays as bycatch. Source: Manta Watch (2022). Available from: https://mantawatchnz.org/threats/#fisher. Accessed on 14th August 2024
Pelagic non-selective fishing	Sunfish	-2	Sunfish are often caught as bycatch. Source: IUCN (2011). Available from: https://www.iucnredlist.org/species/190422/97667070#threats. Accessed on 20th August 2024
Pelagic non-selective fishing	Water quality	-2	Discarded fishing gear creates pollution. Source: opinion
Pelagic non-selective fishing	Biodiversity	-2	Non-selective fishing removes lots of non-target species from the ecosystem. Source: opinion
Pelagic non-selective fishing	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Selective fishing	-2	More of one fishing technique will reduce other techniques. Source: opinion
Pelagic non-selective fishing	Boat use	4	Increased fishing will increase boats in the MPA. Source: opinion
Pelagic non-selective fishing	Anchoring	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Disturbance	2	Movement of nets cause some disturbance, but most disturbance accounted for in the boat use – disturbance edge score. Source: opinion
Pelagic non-selective fishing	Recreation	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Tourism	0	One European study found increased fishery coincided with increases in tourism, this could be site specific and there is a lack of further evidence in literature. The increase could be more linked to cultural heritage than the practice of fishing itself. Source: opinion; Nielsen et al. (2024) https://doi.org/10.1016/j.marpol.2024.106051
Pelagic non-selective fishing	Seaweed farming	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Coastal development	1	Increased fishing activity can increase the need for facilities such as storage, access points, etc. Source: opinion
Pelagic non-selective fishing	Coastal protection	0	No direct relationship. Source: opinion Source: opinion
Pelagic non-selective fishing	Fishing employment	4	Increased fishing will increase jobs in this sector. Source: opinion
Pelagic non-selective fishing	Tourism employment	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Aquaculture employment	0	No direct relationship. Source: opinion

Pelagic non-selective fishing	Cultural heritage	3	Fishing is a part of culture in Nusa Penida as a coastal community. Source: Yunitawati and Clifton (2021) https://doi.org/10.1016/j.marpol.2019.103653
Pelagic non-selective fishing	Community acceptance	0	No direct relationship. Source: opinion, accounted for in the fishing employment – community acceptance edge score. Source: opinion

Table 12. BBN scores given for the influence of selective fishing on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Selective fishing	Seagrass	0	No direct relationship. Source: opinion
Selective fishing	Mangroves	0	No direct relationship. Source: opinion
Selective fishing	Coral Reef	0	No direct relationship. Source: opinion
Selective fishing	Zooplankton	0	No direct relationship. Source: opinion
Selective fishing	Invertebrates	0	No direct relationship. Source: opinion
Selective fishing	Fish	-3	No direct relationship. Source: opinion
Selective fishing	Manta Rays	-1	Manta rays can get caught on long lines as bycatch. Source: IUCN (2018). Available from: https://www.iucnredlist.org/species/195459/214395983#threats. Accessed 4th September 2024
Selective fishing	Sunfish	-1	Sunfish can get caught on long lines as bycatch. Source: IUCN (2011). Available from: https://www.iucnredlist.org/species/190422/97667070#threats. Accessed on 14th August 2024
Selective fishing	Water quality	-1	Some discarded fishing gear creating pollution, but less than non-selective fishing. Source: opinion
Selective fishing	Biodiversity	-1	Likely to reduce biodiversity by taking species from the ecosystem, however less so than non-selective fishing which captures more species. Source: opinion
Selective fishing	Pelagic non-selective fishing	-2	More of one type of fishing will decrease others. Source: opinion
Selective fishing	Selective fishing	0	No direct relationship. Source: opinion
Selective fishing	Boat use	4	More fishing will increase boats in the MPA. Source: opinion
Selective fishing	Anchoring	0	No direct relationship. Source: opinion

Selective fishing	Disturbance	1	Unlikely that the fishing technique causes lots of disturbance, more likely the boat use. Source: opinion
Selective fishing	Recreation	0	No direct relationship. Source: opinion
Selective fishing	Tourism	0	No direct relationship. Source: opinion
Selective fishing	Seaweed farming	0	No direct relationship. Source: opinion
Selective fishing	Coastal development	1	Increased fishing activity can increase the need for facilities such as storage, access points, etc. Source: opinion
Selective fishing	Coastal protection	0	No direct relationship. Source: opinion
Selective fishing	Fishing employment	4	Increased fishing will increase fishing employment. Source: opinion
Selective fishing	Tourism employment	0	No direct relationship. Source: opinion
Selective fishing	Aquaculture employment	0	No direct relationship. Source: opinion
Selective fishing	Cultural heritage	3	Fishing is part of culture in Nusa Penida. Source: Yunitawati and Clifton (2021) https://doi.org/10.1016/j.marpol.2019.103653
Selective fishing	Community acceptance	0	No direct relationship. Source: opinion, accounted for in the fishing employment – community acceptance edge score. Source: opinion

Table 13. BBN scores given for the influence of boat use on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Boat use	Seagrass	-2	Damage from boats contacting the seabed. Source: opinion
Boat use	Mangroves	0	No direct relationship. Source: opinion
Boat use	Coral Reef	-2	Damage from boats contacting the seabed. Source: opinion
Boat use	Zooplankton	0	No direct relationship. Source: opinion
Boat use	Invertebrates	0	No direct relationship. Source: opinion
Boat use	Fish	0	No direct relationship. Source: opinion
Boat use	Manta Rays	-1	Manta rays are often struck by boats and injured. Source: IUCN (2018). Available from: https://www.iucnredlist.org/species/195459/214395983#threats. Accessed 4th September 2024

Boat use	Sunfish	-1	Reports of vessel strikes to sunfish. Source: Schoeman et al. (2020) https://doi.org/10.3389/fmars.2020.00292; various news articles via search engine
Boat use	Water quality	-2	Fuel spills, wastewater and litter from boats impact water quality. Source: opinion
Boat use	Biodiversity	0	No direct relationship. Source: opinion
Boat use	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Boat use	Selective fishing	0	No direct relationship. Source: opinion
Boat use	Boat use	0	No direct relationship. Source: opinion
Boat use	Anchoring	4	More boats result in more need for anchoring. Source: opinion
Boat use	Disturbance	4	Boats cause movement and noise disturbance. Source: opinion
Boat use	Recreation	0	No direct relationship. Source: opinion
Boat use	Tourism	0	No direct relationship. Source: opinion
Boat use	Seaweed farming	0	No direct relationship. Source: opinion
Boat use	Coastal development	2	Likely need for facilities such as jetties etc. Source: opinion
Boat use	Coastal protection	0	No direct relationship. Source: opinion
Boat use	Fishing employment	0	No direct relationship. Source: opinion
Boat use	Tourism employment	0	No direct relationship. Source: opinion
Boat use	Aquaculture employment	0	No direct relationship. Source: opinion
Boat use	Cultural heritage	2	Traditional boats and fishing part of culture. Source: Yunitawati and Clifton (2021) https://doi.org/10.1016/j.marpol.2019.103653
Boat use	Community acceptance	0	No direct relationship. Source: opinion

Table 14. BBN scores given for the influence of anchoring on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Anchoring	Seagrass	-3	Likely damage to seagrass due to physical contact. Source: opinion

Anchoring	Mangroves	0	Unlikely for anchors contacting mangroves. Source: opinion
Anchoring	Coral Reef	-3	Likely scraping and breaking coral. Source: opinion
Anchoring	Zooplankton	0	No direct relationship. Source: opinion
Anchoring	Invertebrates	-1	May cause some direct damage to benthic invertebrates. Source: opinion
Anchoring	Fish	0	No direct relationship. Source: opinion
Anchoring	Manta Rays	0	No direct relationship. Source: opinion
Anchoring	Sunfish	0	No direct relationship. Source: opinion
Anchoring	Water quality	0	No direct relationship. Source: opinion
Anchoring	Biodiversity	0	No direct relationship. Source: opinion
Anchoring	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Anchoring	Selective fishing	0	No direct relationship. Source: opinion
Anchoring	Boat use	0	No direct relationship. Source: opinion
Anchoring	Anchoring	0	No direct relationship. Source: opinion
Anchoring	Disturbance	1	Direct disturbance to the seabed organisms through movement and impact. Source: opinion
Anchoring	Recreation	0	No direct relationship. Source: opinion
Anchoring	Tourism	0	No direct relationship. Source: opinion
Anchoring	Seaweed farming	0	No direct relationship. Source: opinion
Anchoring	Coastal development	0	No direct relationship. Source: opinion
Anchoring	Coastal protection	0	No direct relationship. Source: opinion
Anchoring	Fishing employment	0	No direct relationship. Source: opinion
Anchoring	Tourism employment	0	No direct relationship. Source: opinion
Anchoring	Aquaculture employment	0	No direct relationship. Source: opinion
Anchoring	Cultural heritage	0	No direct relationship. Source: opinion

Anchoring	Community acceptance	0	No direct relationship. Source: opinion

Table 15. BBN scores given for the influence of disturbance on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Disturbance	Seagrass	-2	Trampling, anchoring, boat strikes on seagrass cause damage. Source: Travaille et al. (2015) https://doi.org/10.1016/j.ocecoaman.2015.06.002; Carreño and Lloret (2021) https://doi.org/10.1016/j.ocecoaman.2021.105693
Disturbance	Mangroves	0	No direct relationship. Source: opinion, but disturbance likely impacts water quality which can impact mangroves. Accounted for in water quality – mangrove edge score. Source: opinion
Disturbance	Coral Reef	-2	Trampling, anchoring, boat strikes on coral reefs cause damage. Source: Hannak et al. (2011) https://doi.org/10.1016/j.jenvman.2011.06.012; Flynn and Forrester (2019) https://doi.org/10.7717/peerj.7010
Disturbance	Zooplankton	0	No direct relationship. Source: opinion
Disturbance	Invertebrates	-1	Likely behavioural response to disturbance, may hide etc, not likely a primary threat but still some impact. Source: opinion
Disturbance	Fish	-1	Likely behavioural response to disturbance of moving away, not likely a primary threat but still some impact. Source: opinion
Disturbance	Manta Rays	-2	Likely to avoid disturbed areas, may stop reaching important aggregator sites. Source: opinion
Disturbance	Sunfish	-2	Likely to avoid disturbed areas, may stop reaching important aggregator sites. Source: opinion
Disturbance	Water quality	-1	Turbidity and sediment disturbance decreases water quality. Source: opinion
Disturbance	Biodiversity	0	No direct relationship. Source: opinion
Disturbance	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Disturbance	Selective fishing	0	No direct relationship. Source: opinion
Disturbance	Boat use	0	No direct relationship. Source: opinion
Disturbance	Anchoring	0	No direct relationship. Source: opinion
Disturbance	Disturbance	0	No direct relationship. Source: opinion

Disturbance	Recreation	0	No direct relationship. Source: opinion
Disturbance	Tourism	0	No direct relationship. Source: opinion
Disturbance	Seaweed farming	0	No direct relationship. Source: opinion
Disturbance	Coastal development	0	No direct relationship. Source: opinion
Disturbance	Coastal protection	0	No direct relationship. Source: opinion
Disturbance	Fishing employment	0	No direct relationship. Source: opinion
Disturbance	Tourism employment	0	No direct relationship. Source: opinion
Disturbance	Aquaculture employment	0	No direct relationship. Source: opinion
Disturbance	Cultural heritage	0	No direct relationship. Source: opinion
Disturbance	Community acceptance	0	No direct relationship. Source: opinion

Table 16. BBN scores given for the influence of recreation on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Recreation	Seagrass	0	Recreation can result in trampling, but this accounted for in the disturbance edge scores. Source: opinion
Recreation	Mangroves	0	No direct relationship. Source: opinion. Boat tours take place which could cause damage, but this is accounted for in the boat use edge scores. Source: opinion
Recreation	Coral Reef	0	Recreation can result in trampling, but this accounted for in the disturbance edge scores. Source: opinion
Recreation	Zooplankton	0	No direct relationship. Source: opinion
Recreation	Invertebrates	0	Recreation can result in trampling, but this accounted for in the disturbance edge scores. Source: opinion
Recreation	Fish	0	No direct relationship. Source: opinion
Recreation	Manta Rays	0	No direct relationship. Source: opinion
Recreation	Sunfish	0	No direct relationship. Source: opinion

Recreation	Water quality	-2	Jet ski fuel spills, sunscreen from people swimming etc. Could impact water quality. Source: opinion
Recreation	Biodiversity	0	No direct relationship. Source: opinion
Recreation	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Recreation	Selective fishing	0	No direct relationship. Source: opinion
Recreation	Boat use	4	Increased snorkelling and dive and mangrove tours will increase boat use. Source: opinion
Recreation	Anchoring	0	No direct relationship. Source: opinion
Recreation	Disturbance	4	Presence of people and vessels in the water will create movement and noise
Recreation	Recreation	0	No direct relationship. Source: opinion
Recreation	Tourism	0	No direct relationship. Source: opinion
Recreation	Seaweed farming	0	No direct relationship. Source: opinion
Recreation	Coastal development	2	Likely to need to build facilities such as pontoons and jetties. Source: opinion
Recreation	Coastal protection	0	No direct relationship. Source: opinion
Recreation	Fishing employment	0	No direct relationship. Source: opinion
Recreation	Tourism employment	4	Recreation creates business opportunities for tours, diving etc. Source: opinion
Recreation	Aquaculture employment	0	No direct relationship. Source: opinion
Recreation	Cultural heritage	0	No direct relationship. Source: opinion
Recreation	Community acceptance	-1	Recreation may disrupt local people's access and relationship with the local marine environment and may cause them to be unaccepting.

Table 17. BBN scores given for the influence of tourism on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**

Tourism	Seagrass	0	No direct relationship. Source: opinion
Tourism	Mangroves	0	No direct relationship. Source: opinion
Tourism	Coral Reef	0	No direct relationship. Source: opinion
Tourism	Zooplankton	0	No direct relationship. Source: opinion
Tourism	Invertebrates	0	No direct relationship. Source: opinion
Tourism	Fish	0	No direct relationship. Source: opinion
Tourism	Manta Rays	0	No direct relationship. Source: opinion
Tourism	Sunfish	0	No direct relationship. Source: opinion
Tourism	Water quality	0	No direct relationship. Source: opinion
Tourism	Biodiversity	0	No direct relationship. Source: opinion
Tourism	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Tourism	Selective fishing	1	Recreational fishing may increase. Source: opinion
Tourism	Boat use	4	Increased boats from Bali to transport tourists. Source: opinion
Tourism	Anchoring	0	No direct relationship. Source: opinion
Tourism	Disturbance	0	No direct relationship. Source: opinion
Tourism	Recreation	4	Increased visitors will increase recreation as the main attractions in Nusa Penida are diving, snorkelling etc. Source: opinion
Tourism	Tourism	0	No direct relationship. Source: opinion
Tourism	Seaweed farming	0	No direct relationship. Source: opinion
Tourism	Coastal development	4	Increases in tourism have resulted in a large increase in the building of lodging, restaurants etc from previously idle land or residential areas. Source: Prihadi et al. (2024) https://doi.org/10.55927/fjmr.v3i8.10495
Tourism	Coastal protection	0	No direct relationship. Source: opinion
Tourism	Fishing employment	0	No direct relationship. Source: opinion
Tourism	Tourism employment	4	Increased hotels, restaurants etc. lead to more jobs. Source: opinion
Tourism	Aquaculture employment	0	No direct relationship. Source: opinion

Tourism	Cultural heritage	-1	Influx of tourists could 'dilute' tradition and culture. Source: opinion
Tourism	Community acceptance	1	Tourism could be accepted by locals as brings increased income opportunities, this is mainly accounted for in the tourism employment – community acceptance edge score. Source: opinion

Table 18. BBN scores given for the influence of seaweed farming on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Seaweed farming	Seagrass	0	No reports of damage to seagrass from seaweed farming in the area. Source: Firdausy and Tisdell (1991). http://dx.doi.org/10.22004/ag.econ.206548
Seaweed farming	Mangroves	0	No direct relationship. Source: opinion
Seaweed farming	Coral Reef	0	No reports of damage to coral reef from seaweed farming in the area. Some comments on potential issues but no evidence. Source: Firdausy and Tisdell (1991). http://dx.doi.org/10.22004/ag.econ.206548
Seaweed farming	Zooplankton	0	No direct relationship. Source: opinion
Seaweed farming	Invertebrates	1	The seaweed farms provide habitat and food resources for some invertebrates. Source: opinion
Seaweed farming	Fish	1	The seaweed farms provide habitat and food resources for some fish. Source: opinion
Seaweed farming	Manta Rays	0	No direct relationship. Source: opinion
Seaweed farming	Sunfish	0	No direct relationship. Source: opinion
Seaweed farming	Water quality	0	Seaweed farming does not require the use of fertilisers and fuel and not is not reported to cause pollution. Source: Firdausy and Tisdell (1991). http://dx.doi.org/10.22004/ag.econ.206548
Seaweed farming	Biodiversity	2	Seaweed species add to biodiversity. Source: opinion
Seaweed farming	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Seaweed farming	Selective fishing	0	No direct relationship. Source: opinion
Seaweed farming	Boat use	2	Boats needed to export of seaweed. Source: opinion
Seaweed farming	Anchoring	0	No direct relationship. Source: opinion
Seaweed farming	Disturbance	1	General operational noise and movement, likely in the farm. Source: opinion

Seaweed farming	Recreation	-1	Farms can block access for surfing and diving. Source: Firdausy and Tisdell (1991). http://dx.doi.org/10.22004/ag.econ.206548
Seaweed farming	Tourism	0	Unlikely to drive tourism as not mentioned as a main factor for people visiting. Source: opinion
Seaweed farming	Seaweed farming	0	No direct relationship. Source: opinion
Seaweed farming	Coastal development	2	Facilities such as storage and drying spaces needed. Source: Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Seaweed farming	Coastal protection	1	Likely some wave attenuation. Source: opinion
Seaweed farming	Fishing employment	0	No direct relationship. Source: opinion
Seaweed farming	Tourism employment	0	No direct relationship. Source: opinion
Seaweed farming	Aquaculture employment	4	More farming creates more seaweed farming jobs. Source: opinion
Seaweed farming	Cultural heritage	2	Seaweed farming a large part of the local economy and many employed in this field. Source: Carter et al. (2014) https://doi.org/10.13140/RG.2.1.4264.8166
Seaweed farming	Community acceptance	0	No direct relationship. Source: opinion

Table 19. BBN scores given for the influence of coastal development on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Coastal development	Seagrass	-1	If built directly on this habitat will cause damage, but will often be on land. Source: opinion
Coastal development	Mangroves	-1	If built directly on this habitat will cause damage, but will often be on land. Source: opinion
Coastal development	Coral Reef	-1	If built directly on this habitat will cause damage, but will often be on land. Source: opinion
Coastal development	Zooplankton	0	No direct relationship. Source: opinion
Coastal development	Invertebrates	0	No direct relationship. Source: opinion
Coastal development	Fish	0	No direct relationship. Source: opinion

Coastal development	Manta Rays	0	No direct relationship. Source: opinion
Coastal development	Sunfish	0	No direct relationship. Source: opinion
Coastal development	Water quality	-2	More development likely to cause sediment while building, wastewater etc. Source: opinion
Coastal development	Biodiversity	0	No direct relationship. Source: opinion
Coastal development	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Coastal development	Selective fishing	0	No direct relationship. Source: opinion
Coastal development	Boat use	0	No direct relationship. Source: opinion
Coastal development	Anchoring	0	No direct relationship. Source: opinion
Coastal development	Disturbance	3	Construction would create light, noise and movement. Source: opinion
Coastal development	Recreation	0	No direct relationship. Source: opinion
Coastal development	Tourism	3	Improvement in facilities, such as accommodation and restaurants will attract tourists. Source: opinion
Coastal development	Seaweed farming	0	No direct relationship. Source: opinion
Coastal development	Coastal development	0	No direct relationship. Source: opinion
Coastal development	Coastal protection	0	No direct relationship. Source: opinion
Coastal development	Fishing employment	0	No direct relationship. Source: opinion
Coastal development	Tourism employment	0	No direct relationship. Source: opinion
Coastal development	Aquaculture employment	0	No direct relationship. Source: opinion
Coastal development	Cultural heritage	-2	Could cause removal of traditional infrastructure and landscapes. Source: opinion
Coastal development	Community acceptance	-1	Could be disruptive to local communities. Source: opinion

Table 20. BBN scores given for the influence of coastal protection on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Coastal Protection	Seagrass	2	Benefit from protection from velocity of waves which would cause damage/unsuitable conditions. Source: opinion

Coastal Protection	Mangroves	2	Benefit from protection from velocity of waves which would cause damage/unsuitable conditions. Source: opinion
Coastal Protection	Coral Reef	0	Reef creates coastal protection but doesn't largely benefit from it. Source: opinion
Coastal Protection	Zooplankton	0	No direct relationship. Source: opinion
Coastal Protection	Invertebrates	0	No direct relationship. Source: opinion
Coastal Protection	Fish	1	Juvenile fish benefit from shelter. Source: opinion
Coastal Protection	Manta Rays	1	Attracted to reef area due to sheltered nursery area. Source: opinion
Coastal Protection	Sunfish	0	No direct relationship. Source: opinion
Coastal Protection	Water quality	0	No direct relationship. Source: opinion
Coastal Protection	Biodiversity	0	No direct relationship. Source: opinion
Coastal Protection	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Coastal Protection	Selective fishing	0	No direct relationship. Source: opinion
Coastal Protection	Boat use	0	No direct relationship. Source: opinion
Coastal Protection	Anchoring	0	No direct relationship. Source: opinion
Coastal Protection	Disturbance	0	No direct relationship. Source: opinion
Coastal Protection	Recreation	1	Makes recreational activities possible or more enjoyable. Source: opinion
Coastal Protection	Tourism	0	No direct relationship. Source: opinion
Coastal Protection	Seaweed farming	2	Shelter allows the conditions to cultivate seaweed. Source: opinion
Coastal Protection	Coastal development	0	No direct relationship. Source: opinion
Coastal Protection	Coastal protection	0	No direct relationship. Source: opinion
Coastal Protection	Fishing employment	0	No direct relationship. Source: opinion
Coastal Protection	Tourism employment	0	No direct relationship. Source: opinion
Coastal Protection	Aquaculture employment	0	No direct relationship. Source: opinion

Coastal Protection	Cultural heritage	0	No direct relationship. Source: opinion
Coastal Protection	Community acceptance	2	No direct relationship. Source: opinion

Table 21. BBN scores given for the influence of fishing employment on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Fishing employment	Seagrass	0	No direct relationship. Source: opinion
Fishing employment	Mangroves	0	No direct relationship. Source: opinion
Fishing employment	Coral Reef	0	No direct relationship. Source: opinion
Fishing employment	Zooplankton	0	No direct relationship. Source: opinion
Fishing employment	Invertebrates	0	No direct relationship. Source: opinion
Fishing employment	Fish	0	No direct relationship. Source: opinion
Fishing employment	Manta Rays	0	No direct relationship. Source: opinion
Fishing employment	Sunfish	0	No direct relationship. Source: opinion
Fishing employment	Water quality	0	No direct relationship. Source: opinion
Fishing employment	Biodiversity	0	No direct relationship. Source: opinion
Fishing employment	Pelagic non-selective fishing	4	No direct relationship. Source: opinion
Fishing employment	Selective fishing	4	No direct relationship. Source: opinion
Fishing employment	Boat use	0	No direct relationship. Source: opinion
Fishing employment	Anchoring	0	No direct relationship. Source: opinion
Fishing employment	Disturbance	0	No direct relationship. Source: opinion
Fishing employment	Recreation	0	No direct relationship. Source: opinion
Fishing employment	Tourism	0	No direct relationship. Source: opinion
Fishing employment	Seaweed farming	0	No direct relationship. Source: opinion
Fishing employment	Coastal development	0	No direct relationship. Source: opinion

Fishing employment	Coastal protection	0	No direct relationship. Source: opinion
Fishing employment	Fishing employment	0	No direct relationship. Source: opinion
Fishing employment	Tourism employment	0	Tourism employment is preferred in Nusa Penida so increased fishing jobs are unlikely to take people away from tourism roles. Source: Andréfouët et al. 2021 https://doi.org/10.1016/j.ocecoaman.2021.105586; Putra 2023 https://doi.org/10.36675/btj.v7i3.96
Fishing employment	Aquaculture employment	-1	Aquaculture not reported as a preferred job role so if people find more work in the fishing industry they may stop working in aquaculture. Source: opinion
Fishing employment	Cultural heritage	0	Fishing is part of the culture in Nusa Penida, but this is accounted for in the fishing – cultural heritage edge scores. Source: opinion
Fishing employment	Community acceptance	2	Increased income opportunities likely to make changes more accepted. Source: opinion

Table 22. BBN scores given for the influence of tourism employment on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Tourism employment	Seagrass	0	No direct relationship. Source: opinion
Tourism employment	Mangroves	0	No direct relationship. Source: opinion
Tourism employment	Coral Reef	0	No direct relationship. Source: opinion
Tourism employment	Zooplankton	0	No direct relationship. Source: opinion
Tourism employment	Invertebrates	0	No direct relationship. Source: opinion
Tourism employment	Fish	0	No direct relationship. Source: opinion
Tourism employment	Manta Rays	0	No direct relationship. Source: opinion
Tourism employment	Sunfish	0	No direct relationship. Source: opinion
Tourism employment	Water quality	0	No direct relationship. Source: opinion
Tourism employment	Biodiversity	0	No direct relationship. Source: opinion
Tourism employment	Pelagic non-selective fishing	0	No direct relationship. Source: opinion

Tourism employment	Selective fishing	0	No direct relationship. Source: opinion
Tourism employment	Boat use	0	No direct relationship. Source: opinion
Tourism employment	Anchoring	0	No direct relationship. Source: opinion
Tourism employment	Disturbance	0	No direct relationship. Source: opinion
Tourism employment	Recreation	0	No direct relationship. Source: opinion
Tourism employment	Tourism	0	No direct relationship. Source: opinion
Tourism employment	Seaweed farming	0	No direct relationship. Source: opinion
Tourism employment	Coastal development	0	No direct relationship. Source: opinion
Tourism employment	Coastal protection	0	No direct relationship. Source: opinion
Tourism employment	Fishing employment	-1	People prefer to work in tourism so may leave fishing employment with better tourism job opportunities. Source: opinion
Tourism employment	Tourism employment	0	No direct relationship. Source: opinion
Tourism employment	Aquaculture employment	-3	People switch to tourism employment in preference. Source: opinion
Tourism employment	Cultural heritage	0	No direct relationship. Source: opinion
Tourism employment	Community acceptance	2	More income opportunities likely to make changes more accepted. Source: opinion

Table 23. BBN scores given for the influence of aquaculture jobs on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Aquaculture employment	Seagrass	0	No direct relationship. Source: opinion
Aquaculture employment	Mangroves	0	No direct relationship. Source: opinion
Aquaculture employment	Coral Reef	0	No direct relationship. Source: opinion
Aquaculture employment	Zooplankton	0	No direct relationship. Source: opinion
Aquaculture employment	Invertebrates	0	No direct relationship. Source: opinion
Aquaculture employment	Fish	0	No direct relationship. Source: opinion
Aquaculture employment	Manta Rays	0	No direct relationship. Source: opinion

Aquaculture employment	Sunfish	0	No direct relationship. Source: opinion
Aquaculture employment	Water quality	0	No direct relationship. Source: opinion
Aquaculture employment	Biodiversity	0	No direct relationship. Source: opinion
Aquaculture employment	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Aquaculture employment	Selective fishing	0	No direct relationship. Source: opinion
Aquaculture employment	Boat use	0	No direct relationship. Source: opinion
Aquaculture employment	Anchoring	0	No direct relationship. Source: opinion
Aquaculture employment	Disturbance	0	No direct relationship. Source: opinion
Aquaculture employment	Recreation	0	No direct relationship. Source: opinion
Aquaculture employment	Tourism	0	No direct relationship. Source: opinion
Aquaculture employment	Seaweed farming	4	Increases in people working in the seaweed farms will increase seaweed farming intensity. Source: opinion
Aquaculture employment	Coastal development	0	No direct relationship. Source: opinion
Aquaculture employment	Coastal protection	0	No direct relationship. Source: opinion
Aquaculture employment	Fishing employment	-1	May take people away from fishing employment, many have multiple jobs. Source: opinion
Aquaculture employment	Tourism employment	0	Preference for tourism employment, people unlikely to leave these roles for aquaculture jobs. Source: opinion
Aquaculture employment	Aquaculture employment	0	No direct relationship. Source: opinion
Aquaculture employment	Cultural heritage	0	No direct relationship. Source: opinion
Aquaculture employment	Community acceptance	2	Increases in income opportunities likely to increase acceptance. Source: opinion

Table 24. BBN scores given for the influence of cultural heritage on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Cultural Heritage	Seagrass	0	No direct relationship. Source: opinion
Cultural Heritage	Mangroves	0	No direct relationship. Source: opinion
Cultural Heritage	Coral Reef	0	No direct relationship. Source: opinion
Cultural Heritage	Zooplankton	0	No direct relationship. Source: opinion
Cultural Heritage	Invertebrates	0	No direct relationship. Source: opinion
Cultural Heritage	Fish	0	No direct relationship. Source: opinion
Cultural Heritage	Manta Rays	0	No direct relationship. Source: opinion
Cultural Heritage	Sunfish	0	No direct relationship. Source: opinion
Cultural Heritage	Water quality	0	No direct relationship. Source: opinion
Cultural Heritage	Biodiversity	0	No direct relationship. Source: opinion
Cultural Heritage	Pelagic non-selective fishing	2	Fishing tied with cultural heritage. If heritage is strong, these practices more likely to continue. Source: opinion
Cultural Heritage	Selective fishing	2	Fishing tied with cultural heritage. If heritage is strong, these practices more likely to continue. Source: opinion
Cultural Heritage	Boat use	0	No direct relationship. Boat use part of culture but this is accounted for in the fishing – boat use edge scores. Source: opinion
Cultural Heritage	Anchoring	0	No direct relationship. Source: opinion
Cultural Heritage	Disturbance	0	No direct relationship. Source: opinion
Cultural Heritage	Recreation	-1	Sacred areas or days may restrict recreation. Source: opinion
Cultural Heritage	Tourism	1	Tourism can be driven by a desire to see different cultures. Source: opinion
Cultural Heritage	Seaweed farming	1	Seaweed farming part of culture. If cultural heritage is strong, these practices are likely to continue. Source: opinion
Cultural Heritage	Coastal development	0	No direct relationship. Source: opinion
Cultural Heritage	Coastal protection	0	No direct relationship. Source: opinion
Cultural Heritage	Fishing employment	0	No direct relationship. Source: opinion
Cultural Heritage	Tourism employment	0	No direct relationship. Source: opinion

Cultural Heritage	Aquaculture employment	0	No direct relationship. Source: opinion
Cultural Heritage	Cultural heritage	0	No direct relationship. Source: opinion
Cultural Heritage	Community acceptance	2	Retaining cultural heritage is good for personal wellbeing/ sense of place/ sense of self and therefore is likely to be accepted. Source: opinion

Table 25. BBN scores given for the influence of community acceptance on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Community Acceptance	Seagrass	0	No direct relationship. Source: opinion
Community Acceptance	Mangroves	0	No direct relationship. Source: opinion
Community Acceptance	Coral Reef	0	No direct relationship. Source: opinion
Community Acceptance	Zooplankton	0	No direct relationship. Source: opinion
Community Acceptance	Invertebrates	0	No direct relationship. Source: opinion
Community Acceptance	Fish	0	No direct relationship. Source: opinion
Community Acceptance	Manta Rays	0	No direct relationship. Source: opinion
Community Acceptance	Sunfish	0	No direct relationship. Source: opinion
Community Acceptance	Water quality	0	No direct relationship. Source: opinion
Community Acceptance	Biodiversity	0	No direct relationship. Source: opinion
Community Acceptance	Bottom towed fishing	0	No direct relationship. Source: opinion
Community Acceptance	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Community Acceptance	Selective fishing	0	No direct relationship. Source: opinion
Community Acceptance	Boat use	0	No direct relationship. Source: opinion
Community Acceptance	Anchoring	0	No direct relationship. Source: opinion
Community Acceptance	Disturbance	0	No direct relationship. Source: opinion
Community Acceptance	Recreation	0	No direct relationship. Source: opinion
Community Acceptance	Tourism	0	No direct relationship. Source: opinion
Community Acceptance	Seaweed farming	0	No direct relationship. Source: opinion

Community Acceptance	Coastal development	0	No direct relationship. Source: opinion
Community Acceptance	Coastal protection	0	No direct relationship. Source: opinion
Community Acceptance	Fishing employment	0	No direct relationship. Source: opinion
Community Acceptance	Tourism employment	0	No direct relationship. Source: opinion
Community Acceptance	Aquaculture employment	0	No direct relationship. Source: opinion
Community Acceptance	Cultural heritage	0	No direct relationship. Source: opinion
Community Acceptance	Community acceptance	0	No direct relationship. Source: opinion

Lyme Bay BBN scores and justifications

Table 26. BBN scores given for the influence of sea caves on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Sea caves	Sea caves	0	No direct relationship. Source: opinion
Sea caves	Rocky reefs	0	No direct relationship. Source: opinion
Sea caves	Stony reefs	0	No direct relationship. Source: opinion
Sea caves	Mussels	0	No direct relationship. Source: opinion
Sea caves	Invertebrates	3	Mussels, barnacles and bivalves present in Lyme Bay sea caves, and provides shelter for crabs, lobsters, and crawfish. Source: JNCC (2024). Available from: https://sac.jncc.gov.uk/habitat/H8330/. Accessed on 1st September 2024
Sea caves	Megafauna	0	Some seals may use caves, but the quality of sea cave flora not likely an impact seal presence. Source: JNCC (2024). Available from: https://sac.jncc.gov.uk/species/S1364/. Accessed on 1st September 2024
Sea caves	Fish	3	Shelter for fish such as leopard spotted goby. Source: JNCC (2024). Available from: https://sac.jncc.gov.uk/habitat/H8330/. Accessed on 1st September 2024
Sea caves	Pink sea fans	0	No direct relationship, pink sea fans not found in sea caves but on rocky reefs. Source: Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024

Sea caves	Sunset cup coral	3	Sunset cup corals typically found in caves or under over hangs. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024
Sea caves	Water quality	2	Parts of the sea cave habitat are made up of filter feeders which help water quality. Source: opinion
Sea caves	Biodiversity	4	Many species make up the sea caves. Sponges, corals, hydroids, tube worms etc. Source: JNCC (2024). Available from: https://sac.jncc.gov.uk/habitat/H8330/. Accessed on 1st September 2024
Sea caves	Bottom towed fishing	0	No direct relationship. Source: opinion
Sea caves	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Sea caves	Selective fishing	0	No direct relationship. Source: opinion
Sea caves	Boat use	0	No direct relationship. Source: opinion
Sea caves	Anchoring	0	No direct relationship. Source: opinion
Sea caves	Disturbance	0	No direct relationship. Source: opinion
Sea caves	Recreation	0	No direct relationship. Source: opinion
Sea caves	Tourism	1	Healthy sea cave ecosystems could attract divers. Source: opinion
Sea caves	Mussel farming	0	No direct relationship. Source: opinion
Sea caves	Coastal development	0	No direct relationship. Source: opinion
Sea caves	Coastal protection	0	No direct relationship. Source: opinion
Sea caves	Fishing employment	0	No direct relationship. Source: opinion
Sea caves	Tourism employment	0	No direct relationship. Source: opinion
Sea caves	Aquaculture employment	0	No direct relationship. Source: opinion
Sea caves	Cultural heritage	1	No direct relationship. Source: opinion
Sea caves	Community acceptance	0	No direct relationship. Source: opinion

Table 27. BBN scores given for the influence of rocky reefs on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Rocky reefs	Sea caves	0	No direct relationship. Source: opinion
Rocky reefs	Rocky reefs	0	No direct relationship. Source: opinion
Rocky reefs	Stony reefs	0	No direct relationship. Source: opinion
Rocky reefs	Mussels	0	No direct relationship. Source: opinion
Rocky reefs	Invertebrates	3	Rocky reefs create habitat for invertebrates. Source: GOV.UK (2023). Available from: https://marinedevelopments.blog.gov.uk/2023/02/24/habit-focus-the-importance-of-rocky-and-biogenic-reefs/. Accessed on 8th September 2024; LBFCR (2024). Available from: https://www.lymebayreserve.co.uk/marine-life/reef-species.php. Accessed on 8th September 2024
Rocky reefs	Megafauna	0	No direct relationship. Seals may forage in reefs but for food, but this is accounted for in the fish – megafauna edge score. Source: opinion
Rocky reefs	Fish	3	The reef creates habitat for many fish species. Source: opinion
Rocky reefs	Pink sea fans	3	Pink sea fans correlate with reef presence. Habitat noted as bedrock with relatively strong water movement. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024; Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024
Rocky reefs	Sunset cup coral	2	Sunset cup corals found under overhangs and shaded rocks. Scored higher for cave. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024
Rocky reefs	Water quality	2	Filter feeders from part of the reef and clean the water. Source: opinion
Rocky reefs	Biodiversity	4	Corals and sponges on the reef contribute to biodiversity. Source: opinion
Rocky reefs	Bottom towed fishing	0	No direct relationship. Source: opinion
Rocky reefs	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Rocky reefs	Selective fishing	0	No direct relationship. Source: opinion
Rocky reefs	Boat use	0	No direct relationship. Source: opinion
Rocky reefs	Anchoring	0	No direct relationship. Source: opinion
Rocky reefs	Disturbance	0	No direct relationship. Source: opinion

Rocky reefs	Recreation	0	No direct relationship. Source: opinion
Rocky reefs	Tourism	1	Healthy reef ecosystems attractive to divers. Source: opinion
Rocky reefs	Mussel farming	0	No direct relationship. Source: opinion
Rocky reefs	Coastal development	0	No direct relationship. Source: opinion
Rocky reefs	Coastal protection	3	Reefs disperse wave energy. Source: opinion
Rocky reefs	Fishing employment	0	No direct relationship. Source: opinion
Rocky reefs	Tourism employment	0	No direct relationship. Source: opinion
Rocky reefs	Aquaculture employment	0	No direct relationship. Source: opinion
Rocky reefs	Cultural heritage	1	A landscape that contributes to sense of place. Traditional practice take place in this area. Source: opinion
Rocky reefs	Community acceptance	0	No direct relationship. Source: opinion

Table 28. BBN scores given for the influence of stony reefs on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Stony reefs	Sea caves	0	No direct relationship. Source: opinion
Stony reefs	Rocky reefs	0	No direct relationship. Source: opinion
Stony reefs	Stony reefs	0	No direct relationship. Source: opinion
Stony reefs	Mussels	0	No direct relationship. Source: opinion
Stony reefs	Invertebrates	3	Many shellfish and invertebrate use the reef as habitat. Source: opinion
Stony reefs	Megafauna	0	No direct relationship. Source: opinion
Stony reefs	Fish	3	The reef provides habitat for fish. Source: opinion
Stony reefs	Pink sea fans	3	Pink sea fans found on bedrock. Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024
Stony reefs	Sunset cup coral	2	Sunset cup coral are found under overhangs and shaded rocks. Scored higher for caves. Sunset cup corals found under overhangs and shaded

			rocks. Scored higher for cave. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024
Stony reefs	Water quality	2	Filter feeding species of the reef help water quality. Source: opinion; Ostroumov (2005) https://doi.org/10.1007/1-4020-3030-4_9
Stony reefs	Biodiversity	4	Coral and sponge species contribute to biodiversity. Source: opinion
Stony reefs	Bottom towed fishing	0	No direct relationship. Source: opinion
Stony reefs	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Stony reefs	Selective fishing	0	No direct relationship. Source: opinion
Stony reefs	Boat use	0	No direct relationship. Source: opinion
Stony reefs	Anchoring	0	No direct relationship. Source: opinion
Stony reefs	Disturbance	0	No direct relationship. Source: opinion
Stony reefs	Recreation	0	No direct relationship. Source: opinion
Stony reefs	Tourism	1	Healthy reef ecosystems attractive to divers. Source: opinion
Stony reefs	Mussel farming	0	No direct relationship. Source: opinion
Stony reefs	Coastal development	0	No direct relationship. Source: opinion
Stony reefs	Coastal protection	3	Reefs dissipate wave energy. Source: Source: Harris et al. (2018) https://doi.org/10.1126/sciadv.aao4350
Stony reefs	Fishing employment	0	No direct relationship. Source: opinion
Stony reefs	Tourism employment	0	No direct relationship. Source: opinion
Stony reefs	Aquaculture employment	0	No direct relationship. Source: opinion
Stony reefs	Cultural heritage	1	A landscape that contributes to sense of place. Traditional practice take place in this area. Source: opinion
Stony reefs	Community acceptance	0	Improved ecosystems likely to be accepted. Source: opinion

Table 29. BBN scores given for the influence of mussels on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Mussels	Sea caves	0	No direct relationship. Source: opinion
Mussels	Rocky reefs	0	No direct relationship. Source: opinion
Mussels	Stony reefs	0	No direct relationship. Source: opinion
Mussels	Mussels	0	No direct relationship. Source: opinion
Mussels	Invertebrates	3	Mussel beds provide habitat for invertebrates. They are eaten by crabs and starfish. Source: Mascorda Cabre et al. (2021) https://doi.org/10.1111/raq.12549; Soria et al. (2022) https://doi.org/10.1016/j.ecss.2022.108035; Theuerkauf et al. (2022) https://doi.org/10.1111/raq.12584
Mussels	Megafauna	1	Megafauna such as dolphins and seals sometimes eat mussels. Source: College of the Atlantic (2024). Available from: https://www.coa.edu/allied-whale/education-resources/secondary/seals/#:~:text=gray%20seals%20have%20a%20wide,off%20the%20coast%20of%20Maine. Accessed 5th September 2024; NOAA Fisheries (2024). Available from: https://www.fisheries.noaa.gov/national/outreach-and-education/fun-facts-about-surprising-seals#do-seals-drink; SeaMOR (2025). Available from: https://seamor.org/what-do-bottlenose-dolphins-like-to-eat/. Accessed 5th September 2024
Mussels	Fish	2	Mussels in the larval stage are eaten by fish. Source: Kautsky (1981) Available from: https://oceanrep.geomar.de/id/eprint/56121. Accessed 20th August 2024
Mussels	Pink sea fans	0	No direct relationship. Source: opinion
Mussels	Sunset cup coral	0	No direct relationship. Source: opinion
Mussels	Water quality	2	Mussels are filter feeders which help water quality. Source: opinion
Mussels	Biodiversity	1	Contributes to overall biodiversity by 1 species. Source: opinion
Mussels	Bottom towed fishing	0	No direct relationship. Source: opinion
Mussels	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Mussels	Selective fishing	0	No direct relationship. Source: opinion
Mussels	Boat use	0	No direct relationship. Source: opinion
Mussels	Anchoring	0	No direct relationship. Source: opinion

Mussels	Disturbance	0	No direct relationship. Source: opinion
Mussels	Recreation	0	No direct relationship. Source: opinion
Mussels	Tourism	0	No direct relationship. Source: opinion
Mussels	Mussel farming	4	More mussels will create more mussel farming opportunities. Source: opinion
Mussels	Coastal development	0	No direct relationship. Source: opinion
Mussels	Coastal protection	2	Fixes sediment and reduces erosion by creating stability. Source: Meadows et al. (1998) https://doi.org/10.1144/GSL.SP.1998.139.01.26; Ysebaert et al. (2019) https://doi.org/10.1007/978-3-319-96776-9
Mussels	Fishing employment	0	No direct relationship. Source: opinion
Mussels	Tourism employment	0	No direct relationship. Source: opinion
Mussels	Aquaculture employment	0	No direct relationship. Source: opinion
Mussels	Cultural heritage	1	Mussels are a historic food resource for coastal communities and create a valued marine landscape. Source: opinion
Mussels	Community acceptance	1	Has an economic benefit as provides a food resource, so likely to be increase acceptance. Source: opinion

Table 30. BBN scores given for the influence of invertebrates on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Invertebrates	Sea caves	2	Positive effects on the reef through grazing and nutrient cycling. Source: opinion; Ostroumov (2005) https://doi.org/10.1007/1-4020-3030-4_9; Gibson et al. (2011) https://www.researchgate.net/publication/230604775
Invertebrates	Rocky reefs	2	Positive effects on the reef through grazing and nutrient cycling. Source: opinion; Ostroumov (2005) https://doi.org/10.1007/1-4020-3030-4_9; Gibson et al. (2011) https://www.researchgate.net/publication/230604775
Invertebrates	Stony reefs	2	Positive effects on the reef through grazing and nutrient cycling. Source: opinion; Ostroumov (2005) https://doi.org/10.1007/1-4020-3030-4_9; Gibson et al. (2011) https://www.researchgate.net/publication/230604775
Invertebrates	Mussels	0	Crabs and starfish eat mussels, maybe not enough to cause a decline. Source: opinion; Theuerkauf et al. (2022) https://doi.org/10.1111/raq.12584
Invertebrates	Invertebrates	0	No direct relationship. Source: opinion

Invertebrates	Megafauna	1	Seals and dolphins eat some squid and crustaceans, although mainly fish. Whales eat plankton, small representation of all invertebrates. Source: opinion
Invertebrates	Fish	3	Many fish eat invertebrates. Source: opinion
Invertebrates	Pink sea fans	-1	Some invertebrates eat sea fans (sea slug etc), but also have positive effects on the reef. Source: opinion; Source: Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024; The Wildlife Trust (2024). Available from: https://www.wildlifetrusts.org/wildlife-explorer/marine/anemones-and-corals/pink-sea-fan. Accessed on 12th August 2024
Invertebrates	Sunset cup coral	-1	Some invertebrates eat cup coral (sea slug etc), but also have positive effects on the reef. Source: opinion; Jackson (2008). Available from: https://www.marlin.ac.uk/species/detail/1285. Accessed on 12th August 2024
Invertebrates	Water quality	1	Many invertebrates are filter feeders (bivalves). Source: opinion
Invertebrates	Biodiversity	4	Many invertebrate species contribute to biodiversity. Source: opinion
Invertebrates	Bottom towed fishing	4	Scallop dredging is common in the area so more scallops would increase these opportunities. Source: opinion; Renn et al. (2024) https://doi.org/10.1093/icesjms/fsad204
Invertebrates	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Invertebrates	Selective fishing	4	Scallop diving, pots for lobsters, crabs, and cuttlefish. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024; LBFCR (2024). Available from: https://www.lymebayreserve.co.uk/about/special-area-of-conservation.php. Accessed 1St September 2024
Invertebrates	Boat use	0	No direct relationship. Source: opinion
Invertebrates	Anchoring	0	No direct relationship. Source: opinion
Invertebrates	Disturbance	0	No direct relationship. Source: opinion
Invertebrates	Recreation	0	No direct relationship. Source: opinion
Invertebrates	Tourism	0	No direct relationship. Source: opinion
Invertebrates	Mussel farming	0	No direct relationship. Source: opinion

Invertebrates	Coastal development	0	No direct relationship. Source: opinion
Invertebrates	Coastal protection	0	No direct relationship. Source: opinion
Invertebrates	Fishing employment	0	No direct relationship. Source: opinion
Invertebrates	Tourism employment	0	No direct relationship. Source: opinion
Invertebrates	Aquaculture employment	0	No direct relationship. Source: opinion
Invertebrates	Cultural heritage	1	Scallops, lobsters and crabs all contribute to historic traditional fishing and seafood in the area. Source: opinion
Invertebrates	Community acceptance	1	Increases in economically important species are likely to increase acceptance. Source: opinion

Table 31. BBN scores given for the influence of megafauna on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Megafauna	Sea caves	0	No direct relationship. Source: opinion
Megafauna	Rocky reefs	0	No direct relationship. Source: opinion
Megafauna	Stony reefs	0	No direct relationship. Source: opinion
Megafauna	Mussels	-1	Megafauna such as dolphins and seals sometimes eat mussels. Source: College of the Atlantic (2024). Available from: https://www.coa.edu/allied-whale/education-resources/secondary/seals/#:~:text=gray%20seals%20have%20a%20wide,off%20the%20coast%20of%20Maine. Accessed 5th September 2024; NOAA Fisheries (2024). Available from: https://www.fisheries.noaa.gov/national/outreach-and-education/fun-facts-about-surprising-seals#do-seals-drink; SeaMOR (2025). Available from: https://seamor.org/what-do-bottlenose-dolphins-like-to-eat/. Accessed 5th September 2024
Megafauna	Invertebrates	-1	Seals and dolphins eat some squid and crustaceans, although mainly fish. Whales eat plankton, small representation of all invertebrates. Source: opinion
Megafauna	Megafauna	0	No direct relationship. Source: opinion
Megafauna	Fish	-2	Some megafaunas such as dolphins and seals eat fish. Some, such as turtles, whales do not. Source: opinion

Megafauna	Pink sea fans	0	No direct relationship. Source: opinion
Megafauna	Sunset cup coral	0	No direct relationship. Source: opinion
Megafauna	Water quality	0	No direct relationship. Source: opinion
Megafauna	Biodiversity	2	A few species in the MPA, such as dolphins, seals, whales, sunfish, basking sharks, and turtles. These add moderately to biodiversity. Source: Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024; LBFCR (2024). Available from: https://www.lymebayreserve.co.uk/about/special-area-of-conservation.php. Accessed 1St September 2024; LBFCR (2024). Available from: https://www.lymebayreserve.co.uk/marine-life/. Accessed 1st September 2024
Megafauna	Bottom towed fishing	0	No direct relationship. Source: opinion
Megafauna	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Megafauna	Selective fishing	0	No direct relationship. Source: opinion
Megafauna	Boat use	0	No direct relationship. Source: opinion
Megafauna	Anchoring	0	No direct relationship. Source: opinion
Megafauna	Disturbance	0	No direct relationship. Source: opinion
Megafauna	Recreation	0	No direct relationship. Source: opinion
Megafauna	Tourism	2	The presence of megafauna can benefit wildlife watching tours. Source: opinion
Megafauna	Mussel farming	0	No direct relationship. Source: opinion
Megafauna	Coastal development	0	No direct relationship. Source: opinion
Megafauna	Coastal protection	0	No direct relationship. Source: opinion
Megafauna	Fishing employment	0	No direct relationship. Source: opinion
Megafauna	Tourism employment	0	No direct relationship. Source: opinion
Megafauna	Aquaculture employment	0	No direct relationship. Source: opinion
Megafauna	Cultural heritage	1	Charismatic species in the area such as seals and dolphins can have cultural significance for coastal communities. Source: opinion
Megafauna	Community acceptance	1	Increases in charismatic species that are valued by the community are likely to increase acceptance

Table 32. BBN scores given for the influence of fish on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Fish	Sea caves	2	Reef fish can eat algae from reef, reducing competition and allowing coral to grow. They excrete nutrients to the area for coral to grow. Not all fish will have this benefit. Source: NOAA Fisheries (2022). Available from: https://www.fisheries.noaa.gov/feature-story/how-are-fisheries-and-coral-reefs-connected. Accessed 24th July 2024
Fish	Rocky reefs	2	Reef fish such as parrotfish eat algae from reef, reducing competition and allowing coral to grow. They excrete nutrients to the area for coral to grow. Not all fish will have this benefit. Source: NOAA Fisheries (2022). Available from: https://www.fisheries.noaa.gov/feature-story/how-are-fisheries-and-coral-reefs-connected. Accessed 24th July 2024
Fish	Stony reefs	2	Reef fish such as parrotfish eat algae from reef, reducing competition and allowing coral to grow. They excrete nutrients to the area for coral to grow. Not all fish will have this benefit. Source: NOAA Fisheries (2022). Available from: https://www.fisheries.noaa.gov/feature-story/how-are-fisheries-and-coral-reefs-connected. Accessed 24th July 2024
Fish	Mussels	-2	Mussels in the larval stage are eaten by fish. Source: Kautsky (1981) Available from: https://oceanrep.geomar.de/id/eprint/56121. Accessed 20th August 2024
Fish	Invertebrates	-3	Many fish eat invertebrates. Source: opinion
Fish	Megafauna	2	Some megafaunas such as dolphins and seals eat fish. Some, such as turtles, whales do not. Source: opinion
Fish	Fish	0	No direct relationship. Source: opinion
Fish	Pink sea fans	0	No direct relationship. Source: opinion
Fish	Sunset cup coral	0	No direct relationship. Source: opinion
Fish	Water quality	0	No direct relationship. Source: opinion
Fish	Biodiversity	4	Fish species contribute to biodiversity. Source: opinion
Fish	Bottom towed fishing	2	Increased fishing opportunity, however, a lot of trawling is for scallops rather than fish. Source: opinion
Fish	Pelagic non-selective fishing	3	Increased fish will increase fishing effort, but not such an emphasis on this fishing technique compared to Nusa Penida as trawling is an additional

			fishing technique in Lyme Bay. Predicted to be influenced but not as much. Source: opinion
Fish	Selective fishing	3	Increased fish will increase fishing effort. Selective fishing often (but not always) for invertebrates. Source: opinion
Fish	Boat use	0	No direct relationship. Source: opinion
Fish	Anchoring	0	No direct relationship. Source: opinion
Fish	Disturbance	0	No direct relationship. Source: opinion
Fish	Recreation	0	No direct relationship. Source: opinion
Fish	Tourism	2	Increased fishing opportunities would benefit recreational angling which is popular in the area and therefore increase tourism. Source: opinion; Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024
Fish	Mussel farming	0	No direct relationship. Source: opinion
Fish	Coastal development	0	No direct relationship. Source: opinion
Fish	Coastal protection	0	No direct relationship. Source: opinion
Fish	Fishing employment	0	No direct relationship. Source: opinion
Fish	Tourism employment	0	No direct relationship. Source: opinion
Fish	Aquaculture employment	0	No direct relationship. Source: opinion
Fish	Cultural heritage	1	Historic fishing village so fish contribute to culture. Source: opinion
Fish	Community acceptance	1	Increased fish likely to gain acceptance, but stronger link through jobs/fishing. Source: opinion

Table 33. BBN scores given for the influence of pink sea fans on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Pink sea fans	Sea caves	0	No direct relationship. Source: opinion
Pink sea fans	Rocky reefs	0	No direct relationship. Source: opinion
Pink sea fans	Stony reefs	0	No direct relationship. Source: opinion

Pink sea fans	Mussels	0	No direct relationship. Source: opinion
Pink sea fans	Invertebrates	1	Species use as a species-specific habitat. Source: Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024; The Wildlife Trust (2024). Available from: https://www.wildlifetrusts.org/wildlife-explorer/marine/anemones-and-corals/pink-sea-fan. Accessed on 12th August 2024
Pink sea fans	Megafauna	0	No direct relationship. Source: opinion
Pink sea fans	Fish	1	The species makes up some of the reefs that provide habitat for fish. Source: opinion
Pink sea fans	Pink sea fans	0	No direct relationship. Source: opinion
Pink sea fans	Sunset cup coral	0	No direct relationship. Source: opinion
Pink sea fans	Water quality	1	Filter feeding species. Source: opinion
Pink sea fans	Biodiversity	1	Contributes to overall biodiversity by one species. Source: opinion
Pink sea fans	Bottom towed fishing	0	No direct relationship. Source: opinion
Pink sea fans	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Pink sea fans	Selective fishing	0	No direct relationship. Source: opinion
Pink sea fans	Boat use	0	No direct relationship. Source: opinion
Pink sea fans	Anchoring	0	No direct relationship. Source: opinion
Pink sea fans	Disturbance	0	No direct relationship. Source: opinion
Pink sea fans	Recreation	0	No direct relationship. Source: opinion
Pink sea fans	Tourism	1	Divers attracted to rare species, but not a main driver of tourism, which could be cultural heritage, angling opportunities etc. Source: opinion
Pink sea fans	Mussel farming	0	No direct relationship. Source: opinion
Pink sea fans	Coastal development	0	No direct relationship. Source: opinion
Pink sea fans	Coastal protection	0	No direct relationship. Source: opinion
Pink sea fans	Fishing employment	0	No direct relationship. Source: opinion
Pink sea fans	Tourism employment	0	No direct relationship. Source: opinion
Pink sea fans	Aquaculture employment	0	No direct relationship. Source: opinion

Pink sea fans	Cultural heritage	1	A valued rare species that contributes to the landscape which can help sense of place. Helps make up the identity of the area as coastal towns. Source: opinion
Pink sea fans	Community acceptance	1	The conservation of a valued and unique species is likely to increase acceptance. Source: opinion

Table 34. BBN scores given for the influence of sunset cup coral on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Sunset cup coral	Sea caves	0	No direct relationship. Source: opinion
Sunset cup coral	Rocky reefs	0	No direct relationship. Source: opinion
Sunset cup coral	Stony reefs	0	No direct relationship. Source: opinion
Sunset cup coral	Mussels	0	No direct relationship. Source: opinion
Sunset cup coral	Invertebrates	1	Provides unique substratum habitat for some species. Source: Jackson (2008). Available from: https://www.marlin.ac.uk/species/detail/1285. Accessed on 12th August 2024
Sunset cup coral	Megafauna	0	No direct relationship. Source: opinion
Sunset cup coral	Fish	1	Make up some of the reefs that provide habitat for fish. Source: opinion
Sunset cup coral	Pink sea fans	0	No direct relationship. Source: opinion
Sunset cup coral	Sunset cup coral	0	No direct relationship. Source: opinion
Sunset cup coral	Water quality	1	Filter feeding of corals helps water quality. Source: opinion
Sunset cup coral	Biodiversity	1	Adds to biodiversity by one species. Source: opinion
Sunset cup coral	Bottom towed fishing	0	No direct relationship. Source: opinion
Sunset cup coral	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Sunset cup coral	Selective fishing	0	No direct relationship. Source: opinion
Sunset cup coral	Boat use	0	No direct relationship. Source: opinion
Sunset cup coral	Anchoring	0	No direct relationship. Source: opinion

Sunset cup coral	Disturbance	0	No direct relationship. Source: opinion
Sunset cup coral	Recreation	0	No direct relationship. Source: opinion
Sunset cup coral	Tourism	1	Divers attracted to rare species. However, recreation driven by many other things, such as wrecks, angling, wildlife tours etc. Source: Rees et al. (2016). Available from: https://pearl.plymouth.ac.uk/bms-research/824. Accessed on 20th August 2024; Pearce et al. (2014). Available from: https://www.researchgate.net/publication/267209122_LymeBay_AppendixA_DeskReviewExclFish_180914. Accessed 8th September 2024
Sunset cup coral	Mussel farming	0	No direct relationship. Source: opinion
Sunset cup coral	Coastal development	0	No direct relationship. Source: opinion
Sunset cup coral	Coastal protection	0	No direct relationship. Source: opinion
Sunset cup coral	Fishing employment	0	No direct relationship. Source: opinion
Sunset cup coral	Tourism employment	0	No direct relationship. Source: opinion
Sunset cup coral	Aquaculture employment	0	No direct relationship. Source: opinion
Sunset cup coral	Cultural heritage	1	A valued rare species that contributes to the landscape which can help sense of place. Helps make up the identity of the area as coastal towns. Source: opinion
Sunset cup coral	Community acceptance	1	The conservation of a valued and unique species is likely to increase acceptance. Source: opinion

Table 35. BBN scores given for the influence of water quality on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**score**	**Justification**
Water quality	Sea caves	3	Sediments, nutrients, pathogens, metals and microplastic all damage coral. Algal blooms smother, litter can block sunlight or break coral, sunscreen and pesticides alters phenology. Source: United States Environmental Protection Agency (2025). Available from: https://www.epa.gov/coral-reefs/threats-coral-reefs accessed on 1st Feb 2025
Water quality	Rocky reefs	3	As above
Water quality	Stony reefs	3	As above
Water quality	Mussels	2	Likely to be impacted by pollutants. Source: opinion

Water quality	Invertebrates	1	Likely to be impacted by pollutants. Source: opinion
Water quality	Megafauna	1	Chemical pollution impact dolphin fertility, ghost ropes cause seal entanglement etc. Source: Allen et al. (2012) https://doi.org/10.1016/j.marpolbul.2012.09.005; Jepson et al. (2016) https://doi.org/10.1038/srep18573; Murphy et al. (2010) https://doi.org/10.2960/J.v42.m658
Water quality	Fish	1	Pollution can make fish ill, or cause oxygen depletion causing dead zones, they can ingest plastic. Source: Bailey et al. (2020) https://doi.org/10.1007/978-981-15-3372-3; Savoca et al. (2021) https://doi.org/10.1111/gcb.15533
Water quality	Pink sea fans	1	Evaluated as having 'medium' sensitivity to some heavy pollutants, but also documented to not be overly sensitive to other pollutants such as nutrient enrichment and suspended sediments. Source: Source: Readman and Hiscock (2017). Available from: https://www.marlin.ac.uk/species/detail/1121. Accessed 10th September 2024
Water quality	Sunset cup coral	1	Evaluated as not sensitive to a lot of pollutants but has 'medium' sensitivity to some heavy pollutants. Source: Jackson (2008). Available from: https://www.marlin.ac.uk/species/detail/1285. Accessed on 12th August 2024
Water quality	Water quality	0	No direct relationship. Source: opinion
Water quality	Biodiversity	0	No direct relationship. Source: opinion
Water quality	Bottom towed fishing	0	No direct relationship. Source: opinion
Water quality	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Water quality	Selective fishing	0	No direct relationship. Source: opinion
Water quality	Boat use	0	No direct relationship. Source: opinion
Water quality	Anchoring	0	No direct relationship. Source: opinion
Water quality	Disturbance	0	No direct relationship. Source: opinion
Water quality	Recreation	0	No direct relationship. Source: opinion
Water quality	Tourism	2	Clean water can encourage in-water recreation such as swimming and diving. Source: opinion
Water quality	Mussel farming	0	No direct relationship. Source: opinion
Water quality	Coastal development	0	No direct relationship. Source: opinion

Water quality	Coastal protection	0	No direct relationship. Source: opinion
Water quality	Fishing employment	0	No direct relationship. Source: opinion
Water quality	Tourism employment	0	No direct relationship. Source: opinion
Water quality	Aquaculture employment	0	No direct relationship. Source: opinion
Water quality	Cultural heritage	1	Coastal communities have a cultural link to the marine environment. Good water quality helps keep this environment in good condition and pollution could stop people accessing the marine environment. Source: opinion
Water quality	Community acceptance	1	Better water quality could please local community

Table 36. BBN scores given for the influence of biodiversity on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Biodiversity	Sea caves	0	No direct relationship. Source: opinion
Biodiversity	Rocky reefs	0	No direct relationship. Source: opinion
Biodiversity	Stony reefs	0	No direct relationship. Source: opinion
Biodiversity	Mussels	0	No direct relationship. Source: opinion
Biodiversity	Invertebrates	0	No direct relationship. Source: opinion
Biodiversity	Megafauna	0	No direct relationship. Source: opinion
Biodiversity	Fish	0	No direct relationship. Source: opinion
Biodiversity	Pink sea fans	0	No direct relationship. Source: opinion
Biodiversity	Sunset cup coral	0	No direct relationship. Source: opinion
Biodiversity	Water quality	0	No direct relationship. Source: opinion
Biodiversity	Biodiversity	0	No direct relationship. Source: opinion
Biodiversity	Bottom towed fishing	0	No direct relationship. Source: opinion

Biodiversity	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Biodiversity	Selective fishing	0	No direct relationship. Source: opinion
Biodiversity	Boat use	0	No direct relationship. Source: opinion
Biodiversity	Anchoring	0	No direct relationship. Source: opinion
Biodiversity	Disturbance	0	No direct relationship. Source: opinion
Biodiversity	Recreation	0	No direct relationship. Source: opinion
Biodiversity	Tourism	2	Better biodiversity attractive to divers, less so than Nusa Penida. Source: opinion
Biodiversity	Mussel farming	0	No direct relationship. Source: opinion
Biodiversity	Coastal development	0	No direct relationship. Source: opinion
Biodiversity	Coastal protection	0	No direct relationship. Source: opinion
Biodiversity	Fishing employment	0	No direct relationship. Source: opinion
Biodiversity	Tourism employment	0	No direct relationship. Source: opinion
Biodiversity	Aquaculture employment	0	No direct relationship. Source: opinion
Biodiversity	Cultural heritage	0	No direct relationship. Source: opinion
Biodiversity	Community acceptance	0	No direct relationship. Source: opinion

Table 37. BBN scores given for the influence of bottom towed fishing on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Bottom towed fishing	Sea caves	0	No direct relationship. Source: opinion
Bottom towed fishing	Rocky reefs	-4	Trawling destroys benthic habitats. Source: opinion
Bottom towed fishing	Stony reefs	-4	Trawling destroys benthic habitats. Source: opinion

Bottom towed fishing	Mussels	-2	Trawling destroys benthic habitats and therefore some mussel beds. Mussels on mussel ropes would not be impacted. Source: opinion
Bottom towed fishing	Invertebrates	-4	Scallop dredging takes place in Lyme Bay and this fishing technique directly removes invertebrates (Scallops) from the seabed, and damages or removes other non-target invertebrates such as crabs and starfish through bycatch or direct trawling damage. Source: Jenkins et al. (2001) http://dx.doi.org/10.3354/meps215297; Szostek et al. (2017) https://doi.org/10.1016/j.marenvres.2016.11.006; Singer and Jones (2021) https://doi.org/10.1016/j.marpol.2018.07.004; LBFCR (2024) available from: https://www.lymebayreserve.co.uk/about/road-to-recovery.php. Accessed 20th August 2024
Bottom towed fishing	Megafauna	-1	Megafauna species threatened by fishing as bycatch, however as many such as dolphins and seals are pelagic, highly mobile species, they are likely more threatened by pelagic trawls. Source: opinion
Bottom towed fishing	Fish	-3	Fishing depletes fish stocks, trawling in Lyme Bay often for scallops rather than fish. Source: opinion
Bottom towed fishing	Pink sea fans	-4	Trawling destroys benthic habitats. Source: opinion
Bottom towed fishing	Sunset cup coral	-4	Trawling destroys benthic habitats. Source: opinion
Bottom towed fishing	Water quality	-2	Can often result in discarded fishing gear. Source: opinion
Bottom towed fishing	Biodiversity	-3	Removes many species from the ecosystem. Source: opinion
Bottom towed fishing	Bottom towed fishing	0	No direct relationship. Source: opinion
Bottom towed fishing	Pelagic non-selective fishing	-2	Increase in one type of fishing will lead to decrease in another. Source: opinion
Bottom towed fishing	Selective fishing	-2	Increase in one type of fishing will lead to decrease in another. Source: opinion
Bottom towed fishing	Boat use	4	More fishing means more boats in the MPA. Source: opinion
Bottom towed fishing	Anchoring	-2	Less anchoring when trawling as mobile fishing practices do not need to moor as often. Still predicted to increase overall through the boat use – anchoring edge score. Source: opinion

Bottom towed fishing	Disturbance	4	A high amount of physical disturbance to the seabed. Source: opinion
Bottom towed fishing	Recreation	0	No direct relationship. Source: opinion
Bottom towed fishing	Tourism	0	No direct relationship. Source: opinion
Bottom towed fishing	Mussel farming	0	No direct relationship. Source: opinion
Bottom towed fishing	Coastal development	1	Likely development of more facilities, many already exist as a historic fishing area. Source: opinion
Bottom towed fishing	Coastal protection	0	No direct relationship. Source: opinion
Bottom towed fishing	Fishing employment	4	Increase in fishing leads to increase in fishing employment opportunities. Source: opinion
Bottom towed fishing	Tourism employment	0	No direct relationship. Source: opinion
Bottom towed fishing	Aquaculture employment	0	No direct relationship. Source: opinion
Bottom towed fishing	Cultural heritage	2	Historic fishing villages around Lyme Bay, fishing is part of the culture. Source: opinion
Bottom towed fishing	Community acceptance	0	No direct relationship, accounted for in the fishing employment – community acceptance edge score. Source: opinion

Table 38. BBN scores given for the influence of pelagic non-selective fishing on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Pelagic non-selective fishing	Sea caves	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Rocky reefs	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Stony reefs	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Mussels	0	No direct relationship. Source: opinion

Pelagic non-selective fishing	Invertebrates	-1	No benthic contact but may still capture invertebrates in the water column. Source: opinion
Pelagic non-selective fishing	Megafauna	-2	Can be captured as bycatch, not guaranteed to be released and survive. Source: opinion
Pelagic non-selective fishing	Fish	-4	More fishing will directly reduce fish. Source: opinion
Pelagic non-selective fishing	Pink sea fans	0	No benthic contact so unlikely to cause damage to benthic organisms. Source: opinion
Pelagic non-selective fishing	Sunset cup coral	0	No benthic contact so unlikely to cause damage to benthic organisms. Source: opinion
Pelagic non-selective fishing	Water quality	-2	Fishing activity often result in discarded fishing gear. However, this is only one aspect of ocean pollution. Source: opinion
Pelagic non-selective fishing	Biodiversity	-2	Removes many different species from the ecosystem as a non-selective fishing practice, but avoids benthic species. Source: opinion
Pelagic non-selective fishing	Bottom towed fishing	-2	Increase in one type of fishing can lead to decreases in another. Source: opinion
Pelagic non-selective fishing	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Selective fishing	-2	Increase in one type of fishing can lead to decrease in another. Source: opinion
Pelagic non-selective fishing	Boat use	4	Boat use will increase with more fishing. Source: opinion
Pelagic non-selective fishing	Anchoring	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Disturbance	2	Movement of gear and noise will create disturbance. Source: opinion
Pelagic non-selective fishing	Recreation	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Tourism	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Mussel farming	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Coastal development	1	Likely development of more facilities, many already exist as a historic fishing area. Source: opinion
Pelagic non-selective fishing	Coastal protection	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Fishing employment	4	Fishing employment will increase with more fishing. Source: opinion
Pelagic non-selective fishing	Tourism employment	0	No direct relationship. Source: opinion

Pelagic non-selective fishing	Aquaculture employment	0	No direct relationship. Source: opinion
Pelagic non-selective fishing	Cultural heritage	3	Historic fishing villages around Lyme Bay, fishing is part of the culture. Source: opinion
Pelagic non-selective fishing	Community acceptance	0	No direct relationship, accounted for in the fishing employment – community acceptance edge score. Source: opinion

Table 39. BBN scores given for the influence of selective fishing on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Selective fishing	Sea caves	0	No direct relationship. Fishing unlikely to occur in caves. Source: opinion
Selective fishing	Rocky reefs	-2	Reports of damage from potting to corals and sponges from direct damage. However, some reports that they do not create significant damage. Storms can have an impact as cause movement. Source: Lewis et al. (2009) https://doi.org/10.1080/00288330909510000; Stephenson et al. (2017) https://doi.org/10.1093/icesjms/fsx013; Gall et al. (2020) https://doi.org/10.1016/j.marenvres.2020.105134
Selective fishing	Stony reefs	-2	As above
Selective fishing	Mussels	0	No direct relationship. Potting may cause some damage but lack of evidence of this in the literature. Source: opinion
Selective fishing	Invertebrates	-4	Selective fishing in Lyme Bay consists of fishing for crabs, lobster and scallops so an increase in fishing efforts would decrease these invertebrate species. Source: Renn et al. (2024) https://doi.org/10.1093/icesjms/fsad204
Selective fishing	Megafauna	-1	Long lining could catch megafauna such as turtles as bycatch. Source: opinion
Selective fishing	Fish	-3	Fishing will decrease fish, but also often invertebrate. Source: opinion
Selective fishing	Pink sea fans	-2	Potting reported to significantly damage benthic sessile reef species in some cases, but not all. Source: : Lewis et al. (2009)

			https://doi.org/10.1080/00288330909510000; Stephenson et al. (2017) https://doi.org/10.1093/icesjms/fsx013; Gall et al. (2020) https://doi.org/10.1016/j.marenvres.2020.105134
Selective fishing	Sunset cup coral	-2	As above
Selective fishing	Water quality	-1	Will result in some discarded fishing gear. Source: opinion
Selective fishing	Biodiversity	-1	Removes some species from the ecosystem but not as many as non-selective practices. Source: opinion
Selective fishing	Bottom towed fishing	-2	Increase in one type of fishing likely to reduce another. Source: opinion
Selective fishing	Pelagic non-selective fishing	-2	Increase in one type of fishing likely to reduce another. Source: opinion
Selective fishing	Selective fishing	0	No direct relationship. Source: opinion
Selective fishing	Boat use	4	Increased fishing will increase boat use. Source: opinion
Selective fishing	Anchoring	0	No direct relationship. Source: opinion
Selective fishing	Disturbance	1	Gear movement and noise but less than mobile fishing practices. Source: opinion
Selective fishing	Recreation	0	No direct relationship. Source: opinion
Selective fishing	Tourism	0	No direct relationship. Source: opinion
Selective fishing	Mussel farming	0	No direct relationship. Source: opinion
Selective fishing	Coastal development	1	Likely to require the development of more facilities, however many already exist as the area is a historic fishing area. Source: opinion
Selective fishing	Coastal protection	0	No direct relationship. Source: opinion
Selective fishing	Fishing employment	4	More fishing creates more fishing job opportunities. Source: opinion
Selective fishing	Tourism employment	0	No direct relationship. Source: opinion
Selective fishing	Aquaculture employment	0	No direct relationship. Source: opinion
Selective fishing	Cultural heritage	3	Historic fishing villages around Lyme Bay, fishing is part of the culture. Source: opinion
Selective fishing	Community acceptance	0	No direct relationship, accounted for in the fishing employment – community acceptance edge score. Source: opinion

Table 40. BBN scores given for the influence of Boat use on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Boat use	Sea caves	0	No evidence of boats causing direct damage to this habitat. Source: opinion
Boat use	Rocky reefs	0	No evidence of boats causing direct damage to this habitat. Source: opinion
Boat use	Stony reefs	0	No evidence of boats causing direct damage to this habitat. Source: opinion
Boat use	Mussels	0	No direct relationship. Source: opinion
Boat use	Invertebrates	0	No direct relationship. Source: opinion
Boat use	Megafauna	-1	Dolphins, seals, whales can be subject to boat strikes and be injured or killed. Source: opinion; NOAA (2024). Available from: https://www.fisheries.noaa.gov/insight/understanding-vessel-strikes. Accessed 23rd September 2024
Boat use	Fish	0	No direct relationship. Source: opinion
Boat use	Pink sea fans	0	No evidence of boats causing direct damage to this species. Source: opinion
Boat use	Sunset cup coral	0	No evidence of boats causing direct damage to this species. Source: opinion
Boat use	Water quality	-2	Fuel spills, wastewater and litter from boats impact water quality. Source: opinion
Boat use	Biodiversity	0	No direct relationship. Source: opinion
Boat use	Bottom towed fishing	0	No direct relationship. Source: opinion
Boat use	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Boat use	Selective fishing	0	No direct relationship. Source: opinion
Boat use	Boat use	0	No direct relationship. Source: opinion
Boat use	Anchoring	4	Increased boats will increase frequency of anchoring. Source: opinion
Boat use	Disturbance	4	Boats cause disturbance through noise and movement. Source: opinion
Boat use	Recreation	0	No direct relationship. Source: opinion
Boat use	Tourism	0	No direct relationship. Source: opinion
Boat use	Mussel farming	0	No direct relationship. Source: opinion

Boat use	Coastal development	2	Likely more facilities needed to harbour more boats. Source: opinion
Boat use	Coastal protection	0	No direct relationship. Source: opinion
Boat use	Fishing employment	0	No direct relationship. Source: opinion
Boat use	Tourism employment	0	No direct relationship. Source: opinion
Boat use	Aquaculture employment	0	No direct relationship. Source: opinion
Boat use	Cultural heritage	2	As coastal towns, using boats for recreation or fishing is part of the culture. Source: opinion
Boat use	Community acceptance	0	No direct relationship. Source: opinion

Table 41. BBN scores given for the influence of anchoring on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Anchoring	Sea caves	0	Unlikely to be anchoring in the sea caves. Source: opinion
Anchoring	Rocky reefs	-3	Anchors damage the immediate benthic habitat they come into contact with. Source: opinion
Anchoring	Stony reefs	-3	As above
Anchoring	Mussels	-2	Anchors damage benthic habitats. Wouldn't affect mussels on mussel ropes. Source: opinion
Anchoring	Invertebrates	-1	Likely cause some damage to invertebrates in benthic habitats. Source: opinion
Anchoring	Megafauna	0	No direct relationship. Source: opinion
Anchoring	Fish	0	No direct relationship. Source: opinion
Anchoring	Pink sea fans	-3	Anchors damage benthic habitats. Source: opinion
Anchoring	Sunset cup coral	-3	As above
Anchoring	Water quality	0	No direct relationship. Source: opinion
Anchoring	Biodiversity	0	No direct relationship. Source: opinion

Anchoring	Bottom towed fishing	0	No direct relationship. Source: opinion
Anchoring	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Anchoring	Selective fishing	0	No direct relationship. Source: opinion
Anchoring	Boat use	0	No direct relationship. Source: opinion
Anchoring	Anchoring	0	No direct relationship. Source: opinion
Anchoring	Disturbance	1	Movement of anchors causes physical disturbance. Source: opinion
Anchoring	Recreation	0	No direct relationship. Source: opinion
Anchoring	Tourism	0	No direct relationship. Source: opinion
Anchoring	Mussel farming	0	No direct relationship. Source: opinion
Anchoring	Coastal development	0	No direct relationship. Source: opinion
Anchoring	Coastal protection	0	No direct relationship. Source: opinion
Anchoring	Fishing employment	0	No direct relationship. Source: opinion
Anchoring	Tourism employment	0	No direct relationship. Source: opinion
Anchoring	Aquaculture employment	0	No direct relationship. Source: opinion
Anchoring	Cultural heritage	0	No direct relationship. Source: opinion
Anchoring	Community acceptance	0	No direct relationship. Source: opinion

Table 42. BBN scores given for the influence of disturbance on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Disturbance	Sea caves	-2	Trampling, anchoring, boat strikes on coral reefs cause damage. Source: Hannak et al. (2011) https://doi.org/10.1016/j.jenvman.2011.06.012; Flynn and Forrester (2019) https://doi.org/10.7717/peerj.7010
Disturbance	Rocky reefs	-2	As above
Disturbance	Stony reefs	-2	As above
Disturbance	Mussels	0	No direct relationship. Source: opinion

Disturbance	Invertebrates	-1	Disturbance may displace some invertebrates by causing a behavioural response. Many invertebrates can hide in benthic habitats rather than move away/ avoid an area. Source: opinion
Disturbance	Megafauna	-2	Disturbance may displace some megafauna by causing a behavioural response. Likely to have higher mobility and avoidance behaviour than smaller species. Source: opinion
Disturbance	Fish	-1	Disturbance may displace some fish by causing a behavioural response. Many fish can hide in benthic habitats rather than move away/ avoid an area. Source: opinion
Disturbance	Pink sea fans	-2	Physical disturbance such as trampling from divers can damage benthic habitats. Source: opinion
Disturbance	Sunset cup coral	-2	Physical disturbance such as trampling from divers can damage benthic habitats. Source: opinion
Disturbance	Water quality	-1	Disturbance creates turbidity and sediment. Source: opinion
Disturbance	Biodiversity	0	No direct relationship. Source: opinion
Disturbance	Bottom towed fishing	0	No direct relationship. Source: opinion
Disturbance	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Disturbance	Selective fishing	0	No direct relationship. Source: opinion
Disturbance	Boat use	0	No direct relationship. Source: opinion
Disturbance	Anchoring	0	No direct relationship. Source: opinion
Disturbance	Disturbance	0	No direct relationship. Source: opinion
Disturbance	Recreation	0	No direct relationship. Source: opinion
Disturbance	Tourism	0	No direct relationship. Source: opinion
Disturbance	Mussel farming	0	No direct relationship. Source: opinion
Disturbance	Coastal development	0	No direct relationship. Source: opinion
Disturbance	Coastal protection	0	No direct relationship. Source: opinion
Disturbance	Fishing employment	0	No direct relationship. Source: opinion
Disturbance	Tourism employment	0	No direct relationship. Source: opinion

Disturbance	Aquaculture employment	0	No direct relationship. Source: opinion
Disturbance	Cultural heritage	0	No direct relationship. Source: opinion
Disturbance	Community acceptance	0	No direct relationship. Source: opinion

Table 43. BBN scores given for the influence of recreation on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Recreation	Sea caves	0	No direct relationship. Source: opinion
Recreation	Rocky reefs	0	No direct relationship. Source: opinion
Recreation	Stony reefs	0	No direct relationship. Source: opinion
Recreation	Mussels	0	No direct relationship. Source: opinion
Recreation	Invertebrates	0	No direct relationship. Source: opinion
Recreation	Megafauna	0	No direct relationship. Source: opinion
Recreation	Fish	0	No direct relationship. Source: opinion
Recreation	Pink sea fans	0	No direct relationship. Source: opinion
Recreation	Sunset cup coral	0	No direct relationship. Source: opinion
Recreation	Water quality	-1	Jet ski fuel spills, sunscreen from people swimming etc. Could impact water quality. Source: opinion
Recreation	Biodiversity	0	No direct relationship. Source: opinion
Recreation	Bottom towed fishing	0	No direct relationship. Source: opinion
Recreation	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Recreation	Selective fishing	0	No direct relationship. Source: opinion
Recreation	Boat use	4	Diving and wildlife tours use boats. Source: opinion
Recreation	Anchoring	0	No direct relationship. Source: opinion
Recreation	Disturbance	4	Presence of people in and around the water creates more noise and movement. Source: opinion
Recreation	Recreation	0	No direct relationship. Source: opinion

Recreation	Tourism	0	No direct relationship. Source: opinion
Recreation	Mussel farming	0	No direct relationship. Source: opinion
Recreation	Coastal development	2	Likely to create a need for more facilities. Source: opinion
Recreation	Coastal protection	0	No direct relationship. Source: opinion
Recreation	Fishing employment	0	No direct relationship. Source: opinion
Recreation	Tourism employment	4	More recreation will create more jobs in tours, diving, angling etc. Source: opinion
Recreation	Aquaculture employment	0	No direct relationship. Source: opinion
Recreation	Cultural heritage	0	No direct relationship. Source: opinion
Recreation	Community acceptance	0	No direct relationship. Source: opinion

Table 44. BBN scores given for the influence of tourism on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Evidence**	**Justification**
Tourism	Sea caves	0		No direct relationship. Source: opinion
Tourism	Rocky reefs	0		No direct relationship. Source: opinion
Tourism	Stony reefs	0		No direct relationship. Source: opinion
Tourism	Mussels	0		No direct relationship. Source: opinion
Tourism	Invertebrates	0		No direct relationship. Source: opinion
Tourism	Megafauna	0		No direct relationship. Source: opinion
Tourism	Fish	0		No direct relationship. Source: opinion
Tourism	Pink sea fans	0		No direct relationship. Source: opinion
Tourism	Sunset cup coral	0		No direct relationship. Source: opinion
Tourism	Water quality	0		No direct relationship. Source: opinion

Tourism	Biodiversity	0		No direct relationship. Source: opinion
Tourism	Bottom towed fishing	0		No direct relationship. Source: opinion
Tourism	Pelagic non-selective fishing	0		No direct relationship. Source: opinion
Tourism	Selective fishing	2		Sea angling is a popular recreational activity, so would likely increase with tourism. Source: opinion
Tourism	Boat use	0		No direct relationship. Visitors usually arrive by land. Source: opinion
Tourism	Anchoring	0		No direct relationship. Source: opinion
Tourism	Disturbance	0		No direct relationship. Source: opinion
Tourism	Recreation	4		More tourists will increase the amount of recreation taking place. Source: opinion
Tourism	Tourism	0		No direct relationship. Source: opinion
Tourism	Mussel farming	0		No direct relationship. Source: opinion
Tourism	Coastal development	4		Tourism creates a need for accommodation, car parks, restaurants etc. Source: opinion
Tourism	Coastal protection	0		No direct relationship. Source: opinion
Tourism	Fishing employment	0		No direct relationship. Source: opinion
Tourism	Tourism employment	4	Opinion	More tourism increases tourism job opportunities. Source: opinion
Tourism	Aquaculture employment	0	Opinion	No direct relationship. Source: opinion
Tourism	Cultural heritage	2	Opinion	Towns surrounding Lyme Bay are historic seaside towns that attract holidaymakers. Source: opinion
Tourism	Community acceptance	1	Opinion	Local community likely to be accepting of ongoing tourism as part of culture and economy. Source: opinion

Table 45. BBN scores given for the influence of mussel farming on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Evidence**	**Justification**

Mussel farming	Sea caves	0		No direct relationship. Source: opinion
Mussel farming	Rocky reefs	0		No direct relationship. Source: opinion
Mussel farming	Stony reefs	0		No direct relationship. Source: opinion
Mussel farming	Mussels	-2		Mussel farming will add many mussel to the environment, however it will also harvest a lot of them. Source: opinion
Mussel farming	Invertebrates	0		No direct relationship. Source: opinion
Mussel farming	Megafauna	0		No direct relationship. Source: opinion
Mussel farming	Fish	0		No direct relationship. Source: opinion
Mussel farming	Pink sea fans	0		No direct relationship. Source: opinion
Mussel farming	Sunset cup coral	0		No direct relationship. Source: opinion
Mussel farming	Water quality	0		No direct relationship. Source: opinion
Mussel farming	Biodiversity	0		No direct relationship. Source: opinion
Mussel farming	Bottom towed fishing	-1		Mussel farms create an area where trawling cannot take place. Source: Bridger (2022) https://doi.org/10.1002/aff2.77
Mussel farming	Pelagic non-selective fishing	-1		As above
Mussel farming	Selective fishing	0		No direct relationship. Source: opinion
Mussel farming	Boat use	3		Boats needed to operation the mussel farm. Source: opinion
Mussel farming	Anchoring	0		No direct relationship. Source: opinion
Mussel farming	Disturbance	2		Will create noise and movement. More of this is accounted for through the boat use – disturbance edge score. Source: opinion
Mussel farming	Recreation	0		No direct relationship. Source: opinion
Mussel farming	Tourism	0		No direct relationship. Source: opinion
Mussel farming	Mussel farming	0		No direct relationship. Source: opinion
Mussel farming	Coastal development	2		Likely to be a need to create facilities. Source: opinion
Mussel farming	Coastal protection	0		No direct relationship. Source: opinion
Mussel farming	Fishing employment	0		No direct relationship. Source: opinion
Mussel farming	Tourism employment	0		No direct relationship. Source: opinion

Mussel farming	Aquaculture employment	4		More mussel farming creates more aquaculture employment. Source: opinion
Mussel farming	Cultural heritage	2		Historic fishing area and coastal towns, maritime activity part of the culture. Source: opinion
Mussel farming	Community acceptance	0		No direct relationship. Source: opinion

Table 46. BBN scores given for the influence of coastal development on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Coastal Development	Sea caves	0	No direct relationship. Source: opinion
Coastal Development	Rocky reefs	0	No direct relationship. Source: opinion
Coastal Development	Stony reefs	0	No direct relationship. Source: opinion
Coastal Development	Mussels	0	No direct relationship. Source: opinion
Coastal Development	Invertebrates	0	No direct relationship. Source: opinion
Coastal Development	Megafauna	0	No direct relationship. Source: opinion
Coastal Development	Fish	0	No direct relationship. Source: opinion
Coastal Development	Pink sea fans	0	No direct relationship. Source: opinion
Coastal Development	Sunset cup coral	0	No direct relationship. Source: opinion
Coastal Development	Water quality	-2	Increased sewage, sediment when constructing etc. Source: opinion
Coastal Development	Biodiversity	0	No direct relationship. Source: opinion
Coastal Development	Bottom towed fishing	0	No direct relationship. Source: opinion
Coastal Development	Pelagic non-selective fishing	0	No direct relationship. Source: opinion

Coastal Development	Selective fishing	0	No direct relationship. Source: opinion
Coastal Development	Boat use	0	No direct relationship. Source: opinion
Coastal Development	Anchoring	0	No direct relationship. Source: opinion
Coastal Development	Disturbance	3	Light pollution and noise pollution from construction etc. Source: opinion
Coastal Development	Recreation	0	No direct relationship. Source: opinion
Coastal Development	Tourism	3	More facilities will attract more people. Source: opinion
Coastal Development	Mussel farming	0	No direct relationship. Source: opinion
Coastal Development	Coastal development	0	No direct relationship. Source: opinion
Coastal Development	Coastal protection	0	No direct relationship. Source: opinion
Coastal Development	Fishing employment	0	No direct relationship. Source: opinion
Coastal Development	Tourism employment	0	No direct relationship. Source: opinion
Coastal Development	Aquaculture employment	0	No direct relationship. Source: opinion
Coastal Development	Cultural heritage	-1	May result in less of the historic features in the area, and may reduce traditional practices/ways of life. Source: opinion
Coastal Development	Community acceptance	-1	May reduce acceptance as may encroach on locals' way of life and relationship with the area. Source: opinion

Table 47. BBN scores given for the influence of coastal protection on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Coastal protection	Sea caves	0	No direct relationship. Source: opinion
Coastal protection	Rocky reefs	0	No direct relationship. Source: opinion
Coastal protection	Stony reefs	0	No direct relationship. Source: opinion
Coastal protection	Mussels	0	No direct relationship. Source: opinion

Coastal protection	Invertebrates	0	No direct relationship. Source: opinion
Coastal protection	Megafauna	1	Provides shelter for seal pups (for example in sea caves). Source: opinion
Coastal protection	Fish	1	Provides shelter for juvenile fish. Source: opinion
Coastal protection	Pink sea fans	0	No direct relationship. Source: opinion
Coastal protection	Sunset cup coral	0	No direct relationship. Source: opinion
Coastal protection	Water quality	0	No direct relationship. Source: opinion
Coastal protection	Biodiversity	0	No direct relationship. Source: opinion
Coastal protection	Bottom towed fishing	0	No direct relationship. Source: opinion
Coastal protection	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Coastal protection	Selective fishing	0	No direct relationship. Source: opinion
Coastal protection	Boat use	0	No direct relationship. Source: opinion
Coastal protection	Anchoring	0	No direct relationship. Source: opinion
Coastal protection	Disturbance	0	No direct relationship. Source: opinion
Coastal protection	Recreation	1	Likely to be able to dive, snorkel, paddleboard etc in sheltered waters. Source: opinion
Coastal protection	Tourism	0	No direct relationship. Source: opinion
Coastal protection	Mussel farming	0	No direct relationship. Source: opinion
Coastal protection	Coastal development	0	No direct relationship. Source: opinion
Coastal protection	Coastal protection	0	No direct relationship. Source: opinion
Coastal protection	Fishing employment	0	No direct relationship. Source: opinion
Coastal protection	Tourism employment	0	No direct relationship. Source: opinion
Coastal protection	Aquaculture employment	0	No direct relationship. Source: opinion
Coastal protection	Cultural heritage	0	No direct relationship. Source: opinion
Coastal protection	Community acceptance	2	Likely to be accepting of an ecosystem service. Source: opinion

Table 48. BBN scores given for the influence of fishing employment on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Fishing employment	Sea caves	0	No direct relationship. Source: opinions
Fishing employment	Rocky reefs	0	No direct relationship. Source: opinions
Fishing employment	Stony reefs	0	No direct relationship. Source: opinions
Fishing employment	Mussels	0	No direct relationship. Source: opinion
Fishing employment	Invertebrates	0	No direct relationship. Source: opinions
Fishing employment	Megafauna	0	No direct relationship. Source: opinions
Fishing employment	Fish	0	No direct relationship. Source: opinions
Fishing employment	Pink sea fans	0	No direct relationship. Source: opinions
Fishing employment	Sunset cup coral	0	No direct relationship. Source: opinions
Fishing employment	Water quality	0	No direct relationship. Source: opinions
Fishing employment	Biodiversity	0	No direct relationship. Source: opinions
Fishing employment	Bottom towed fishing	4	More people working in fishing jobs will result in increases in fishing. Source: opinion
Fishing employment	Pelagic non-selective fishing	4	As above
Fishing employment	Selective fishing	4	As above
Fishing employment	Boat use	0	No direct relationship. Source: opinions
Fishing employment	Anchoring	0	No direct relationship. Source: opinions
Fishing employment	Disturbance	0	No direct relationship. Source: opinions
Fishing employment	Recreation	0	No direct relationship. Source: opinions
Fishing employment	Tourism	0	No direct relationship. Source: opinions
Fishing employment	Mussel farming	0	No direct relationship. Source: opinions
Fishing employment	Coastal development	0	No direct relationship. Source: opinions

Fishing employment	Coastal protection	0	No direct relationship. Source: opinions
Fishing employment	Fishing employment	0	No direct relationship. Source: opinions
Fishing employment	Tourism employment	0	Different skills needed for both industries so it is unlikely that an increase in fishing jobs would take away from the tourism workforce. Source: opinion
Fishing employment	Aquaculture employment	-1	May move people away from mussel farming as both involve similar skills background. Source: opinion
Fishing employment	Cultural heritage	0	No direct relationship. Cultural heritage in fishing accounted for in fishing – cultural heritage edge score. Source: opinion
Fishing employment	Community acceptance	2	Increases in employment opportunities likely to be accepted by community as they are positive for local people and economy. Source: opinion

Table 49. BBN scores given for the influence of tourism employment on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Tourism employment	Sea caves	0	No direct relationship. Source: opinion
Tourism employment	Rocky reefs	0	No direct relationship. Source: opinion
Tourism employment	Stony reefs	0	No direct relationship. Source: opinion
Tourism employment	Mussels	0	No direct relationship. Source: opinion
Tourism employment	Invertebrates	0	No direct relationship. Source: opinion
Tourism employment	Megafauna	0	No direct relationship. Source: opinion
Tourism employment	Fish	0	No direct relationship. Source: opinion
Tourism employment	Pink sea fans	0	No direct relationship. Source: opinion
Tourism employment	Sunset cup coral	0	No direct relationship. Source: opinion
Tourism employment	Water quality	0	No direct relationship. Source: opinion
Tourism employment	Biodiversity	0	No direct relationship. Source: opinion
Tourism employment	Bottom towed fishing	0	No direct relationship. Source: opinion
Tourism employment	Pelagic non-selective fishing	0	No direct relationship. Source: opinion

Tourism employment	Selective fishing	0	No direct relationship. Source: opinion
Tourism employment	Boat use	0	No direct relationship. Source: opinion
Tourism employment	Anchoring	0	No direct relationship. Source: opinion
Tourism employment	Disturbance	0	No direct relationship. Source: opinion
Tourism employment	Recreation	0	No direct relationship. Source: opinion
Tourism employment	Tourism	0	No direct relationship. Source: opinion
Tourism employment	Mussel farming	0	No direct relationship. Source: opinion
Tourism employment	Coastal development	0	No direct relationship. Source: opinion
Tourism employment	Coastal protection	0	No direct relationship. Source: opinion
Tourism employment	Fishing employment	0	Different skills needed for both industries so it is unlikely that an increase in tourism jobs would take away from the fishing workforce. Source: opinion
Tourism employment	Tourism employment	0	No direct relationship. Source: opinion
Tourism employment	Aquaculture employment	0	Different skills needed for both industries so it is unlikely that an increase in tourism jobs would take away from the aquaculture workforce. Source: opinion
Tourism employment	Cultural heritage	0	No direct relationship. Source: opinion
Tourism employment	Community acceptance	2	Increases in employment opportunities likely to be accepted by community as they are positive for local people and economy. Source: opinion

Table 50. BBN scores given for the influence of aquaculture employment on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Aquaculture employment	Sea caves	0	No direct relationship. Source: opinion
Aquaculture employment	Rocky reefs	0	No direct relationship. Source: opinion
Aquaculture employment	Stony reefs	0	No direct relationship. Source: opinion
Aquaculture employment	Mussels	0	No direct relationship. Source: opinion
Aquaculture employment	Invertebrates	0	No direct relationship. Source: opinion

Aquaculture employment	Megafauna	0	No direct relationship. Source: opinion
Aquaculture employment	Fish	0	No direct relationship. Source: opinion
Aquaculture employment	Pink sea fans	0	No direct relationship. Source: opinion
Aquaculture employment	Sunset cup coral	0	No direct relationship. Source: opinion
Aquaculture employment	Water quality	0	No direct relationship. Source: opinion
Aquaculture employment	Biodiversity	0	No direct relationship. Source: opinion
Aquaculture employment	Bottom towed fishing	0	No direct relationship. Source: opinion
Aquaculture employment	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Aquaculture employment	Selective fishing	0	No direct relationship. Source: opinion
Aquaculture employment	Boat use	0	No direct relationship. Source: opinion
Aquaculture employment	Anchoring	0	No direct relationship. Source: opinion
Aquaculture employment	Disturbance	0	No direct relationship. Source: opinion
Aquaculture employment	Recreation	0	No direct relationship. Source: opinion
Aquaculture employment	Tourism	0	No direct relationship. Source: opinion
Aquaculture employment	Mussel farming	4	More people working in aquaculture will intensify the amount of mussel farming taking place. Source: opinion
Aquaculture employment	Coastal development	0	No direct relationship. Source: opinion
Aquaculture employment	Coastal protection	0	No direct relationship. Source: opinion
Aquaculture employment	Fishing employment	-1	May move people away from fishing as both involve similar skills background. Source: opinion
Aquaculture employment	Tourism employment	0	People unlikely to leave tourism employment to utilise aquaculture jobs, as both involve different skill sets, possibly different demographics such as age. Source: opinion
Aquaculture employment	Aquaculture employment	0	No direct relationship. Source: opinion
Aquaculture employment	Cultural heritage	0	Cultural significance already accounted for in mussel farming – cultural heritage edge score. Source: opinion
Aquaculture employment	Community acceptance	2	Increases in employment opportunities likely to be accepted by community as they are positive for local people and economy. Source: opinion

Table 51. BBN scores given for the influence of cultural heritage on all child nodes, including justification and source of any evidence used.

Parent node	Child node	Score	Justification
Cultural heritage	Sea caves	0	No direct relationship. Source: opinion
Cultural heritage	Rocky reefs	0	No direct relationship. Source: opinion
Cultural heritage	Stony reefs	0	No direct relationship. Source: opinion
Cultural heritage	Mussels	0	No direct relationship. Source: opinion
Cultural heritage	Invertebrates	0	No direct relationship. Source: opinion
Cultural heritage	Megafauna	0	No direct relationship. Source: opinion
Cultural heritage	Fish	0	No direct relationship. Source: opinion
Cultural heritage	Pink sea fans	0	No direct relationship. Source: opinion
Cultural heritage	Sunset cup coral	0	No direct relationship. Source: opinion
Cultural heritage	Water quality	0	No direct relationship. Source: opinion
Cultural heritage	Biodiversity	0	No direct relationship. Source: opinion
Cultural heritage	Bottom towed fishing	1	Historic fishing area, fishing is part of the local culture. Trawling not so common since long standing bans. Source: opinion
Cultural heritage	Pelagic non-selective fishing	2	Historic fishing area, fishing is part of the local culture. Source: opinion
Cultural heritage	Selective fishing	2	Historic fishing area, fishing is part of the local culture. Source: opinion
Cultural heritage	Boat use	1	Maritime activities part of culture. Source: opinion
Cultural heritage	Anchoring	0	No direct relationship. Source: opinion
Cultural heritage	Disturbance	0	No direct relationship. Source: opinion
Cultural heritage	Recreation	1	Recreational activities in the MPA form part of the culture of seaside towns. Source: opinion
Cultural heritage	Tourism	2	People attracted to the fishing village. More so than Nusa Penida, where reef is attraction. Source: opinion
Cultural heritage	Mussel farming	1	No direct relationship. Source: opinion
Cultural heritage	Coastal development	0	No direct relationship. Source: opinion

Cultural heritage	Coastal protection	0	No direct relationship. Source: opinion
Cultural heritage	Fishing employment	0	No direct relationship. Source: opinion
Cultural heritage	Tourism employment	0	No direct relationship. Source: opinion
Cultural heritage	Aquaculture employment	0	No direct relationship. Source: opinion
Cultural heritage	Cultural heritage	0	No direct relationship. Source: opinion
Cultural heritage	Community acceptance	2	Cultural heritage is good for community wellbeing and likely to increase acceptance. Source: opinion

Table 52. BBN scores given for the influence of community acceptance on all child nodes, including justification and source of any evidence used.

Parent node	**Child node**	**Score**	**Justification**
Community acceptance	Sea caves	0	No direct relationship. Source: opinion
Community acceptance	Rocky reefs	0	No direct relationship. Source: opinion
Community acceptance	Stony reefs	0	No direct relationship. Source: opinion
Community acceptance	Mussels	0	No direct relationship. Source: opinion
Community acceptance	Invertebrates	0	No direct relationship. Source: opinion
Community acceptance	Megafauna	0	No direct relationship. Source: opinion
Community acceptance	Fish	0	No direct relationship. Source: opinion
Community acceptance	Pink sea fans	0	No direct relationship. Source: opinion
Community acceptance	Sunset cup coral	0	No direct relationship. Source: opinion
Community acceptance	Water quality	0	No direct relationship. Source: opinion
Community acceptance	Biodiversity	0	No direct relationship. Source: opinion
Community acceptance	Bottom towed fishing	0	No direct relationship. Source: opinion
Community acceptance	Pelagic non-selective fishing	0	No direct relationship. Source: opinion
Community acceptance	Selective fishing	0	No direct relationship. Source: opinion
Community acceptance	Boat use	0	No direct relationship. Source: opinion

Community acceptance	Anchoring	0	No direct relationship. Source: opinion
Community acceptance	Disturbance	0	No direct relationship. Source: opinion
Community acceptance	Recreation	0	No direct relationship. Source: opinion
Community acceptance	Tourism	0	No direct relationship. Source: opinion
Community acceptance	Mussel farming	0	No direct relationship. Source: opinion
Community acceptance	Coastal development	0	No direct relationship. Source: opinion
Community acceptance	Coastal protection	0	No direct relationship. Source: opinion
Community acceptance	Fishing employment	0	No direct relationship. Source: opinion
Community acceptance	Tourism employment	0	No direct relationship. Source: opinion
Community acceptance	Aquaculture employment	0	No direct relationship. Source: opinion
Community acceptance	Cultural heritage	0	No direct relationship. Source: opinion
Community acceptance	Community acceptance	0	No direct relationship. Source: opinion