Cook Islands Marine Ecosystem Services Valuation

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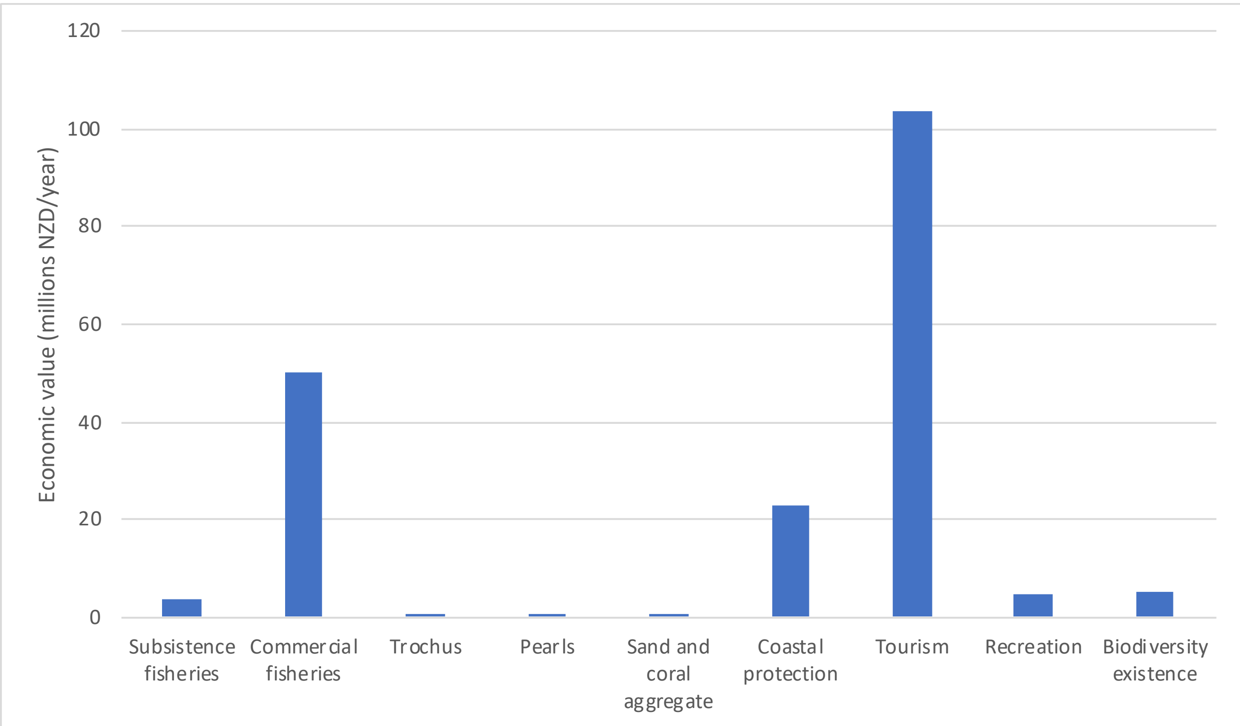
Executive Summary

The exclusive economic zone of the Cook Islands, nearly 1,960,000 km^2 of ocean, is 7,000 times larger than the country's land area of just 240km^2. Coastal and marine resources provide the Government of the Cook Islands, businesses and households with many real and measurable benefits. Without a doubt, the country's largest stock of natural wealth lies in the sea.

The role that natural ecosystems, especially marine ecosystems, play in human wellbeing is often overlooked or taken for granted. The benefits humans receive from ecosystems, called *ecosystem services*[1], are often hidden because markets do not directly reveal their value; nature provides these services for free. Failure to recognise the role that marine ecosystems play in supporting livelihoods, *economic activity*, and human wellbeing has, in many instances, led to inequitable and unsustainable marine resource management decisions.

This report describes, quantifies and, where possible, estimates the *economic value* of the Cook Islands' marine and coastal resources. The key marine ecosystem services that are assessed in detail are: subsistence and commercial fishing; trochus; pearls; sand and coral aggregate; seabed minerals; coastal protection; tourism; recreation; and existence values related to marine biodiversity. The economic values of these services in 2019 are summarised in the figure below. Other services are explored as well, but scarcity of data about many of these ecosystem services prevents estimation of the *total economic value* of all services, so the values below should be regarded as minimum estimates.

Economic values of marine and coastal ecosystem services in the Cook Islands in 2019



[1] Throughout the report, terms in italics are explained in the glossary (Appendix I: Glossary).

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Acronyms

CBA	Cost-Benefit Analysis
CBD	Convention on Biological Diversity
CCZ	Clarion Clipperton Zone
CI	Confidence interval
CIMP	Cook Islands Marine Park (synonymous with Marae Moana)
CITES	Convention on International Trade in Endangered Species
CIT	Cook Islands Tourism Corporation
CO_2	Carbon dioxide
CPD	Cook Islands Census of Population and Dwelling
CPI	Consumer Price Index
CPUE	Catch per unit effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCE	Discrete choice model
DSM	Deep-sea mineral
DWFN	Distant water fishing nation
ECF	Ecosystem contribution factor
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ESP	Ecosystem Services Partnership
ESVD	Ecosystem Services Valuation Database
FAO	Food and Agriculture Organization
FFA	Pacific Islands Forum Fisheries Agency
FOB	Free-on-board
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information Systems
GIZ	German Agency for International Cooperation
GNI	Gross National Income
HDI	Human Development Index
HIES	Household Income and Expenditure Survey
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature

MACBIO	Marine and Coastal Biodiversity in Pacific Island Countries
MESP	Marine Ecosystem Services Partnership
MESV	Marine Ecosystem Services Valuation
MFEM	Ministry of Finance and Economic Management
MMCO	Marae Moana Coordination Office
MMR	Ministry of Marine Resources
MPA	Marine protected area
MSP	Marine spatial planning
MSY	Maximum sustainable yield
NBSAP	National Biodiversity Strategic Action Plan
NES	Cook Islands National Environment Service
NGO	Non-government organisation
nm	nautical miles
NMMSP	National Marae Moana Spatial Plan
NSDP	National Sustainable Development Plan
NZD	New Zealand Dollar
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PICTs	Pacific Island Countries and Territories
PIFS	Pacific Islands Forum Secretariat
RESCCUE	Restoration of Ecosystems Services against Climate Change Unfavourable Effects
R2R	Ridge to Reef
SBM	Seabed minerals
SCC	Social cost of carbon
SDG	Sustainable Development Goals
SEEA	System of Environmental Economic Accounting
SMA	Special Management Area
SMS	Seafloor massive sulphides
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total economic value
UNDP	United Nations Development Program
UNSD	United Nations Statistics Division

VAT	Value added tax
WCPFC	Western and Central Pacific Fisheries Commission
WTP	Willingness-to-pay

1 Introduction

1.1 Ridge to Reef project

The Cook Islands Ridge to Reef (R2R) project is funded by the Global Environment Facility (GEF) in partnership with the Cook Islands Government with support from the United Nations Development Program (UNDP). The project aims to enhance the capacity of the Cook Islands to effectively manage its protected areas and sustainably manage its productive landscapes at local scales, while considering food security and livelihoods. This includes the operationalisation of the Cook Island Marine Park (CIMP) and the establishment and strengthening of various forms of protected and locally managed areas within the CIMP, including protected natural areas, community conservation areas, and ra'ui sites[2]. When the R2R project was initially designed and commenced in July 2015, the CIMP covered approximately 1.1 million km^2 of the Cook Islands southern Exclusive Economic Zone (EEZ), but has since been renamed as Marae Moana and extended to cover the entire 1.96 million km^2 Cook Islands EEZ.

The R2R project aims to support the Cook Islands in strengthening integrated landscape approaches to sustainable environmental management and conservation across key sectors such as fisheries, tourism and agriculture. This includes maintaining traditional resource management and conservation approaches, including a leading role for traditional and local leaders and local communities, while also integrating these traditional systems into a formal legal and institutional system of protected areas.

The project has been designed to engineer a paradigm shift in the management of marine and terrestrial protected areas from a site-centric approach to a holistic 'ridge to reef' management approach, whereby tourism and agriculture activities in production landscapes adjacent to marine and terrestrial protected areas will be managed to reduce threats to biodiversity.

The project started in July 2015 (upon signature of the project document) and following two project extensions was extended to close on 6 June 2021.

The Cook Islands National Environment Service (NES) is the lead executing agency for R2R, responsible for project management, coordination and collaboration with implementation partners.

The project has seven output areas as follows:

- Output 1.1: Strengthened legal/ regulatory and policy frameworks for protected areas
- Output 1.2: Expanded and strengthened management systems for protected areas
- Output 1.3: Strengthened institutional coordination and capacities at the national and local levels for the participatory management of protected areas
- Output 1.4: Financial sustainability framework developed for system of protected areas
- Output 2.1: Ridge to Reef approaches integrated into land use and development planning
- Output 2.2: Biodiversity conservation mainstreamed into agriculture sector
- Output 2.3: Biodiversity conservation mainstreamed into tourism sector.

This Marine Ecosystem Services Valuation (MESV) study forms part of outputs 1.2 and 1.3 of the Cook Islands R2R Project.

[2] Ra'ui: traditional form of protected area as used in Cook Islands

1.2 Problem statement

The people and economies of the Pacific Island Countries and Territories (PICTs) depend to a large extent on marine and coastal ecosystems but marine resource management arguably receives insufficient attention in national plans and strategies (e.g. strategies relating to national development planning, tourism, food security, livelihoods, disaster mitigation and climate change adaptation) (MSWG 2005; PIFS 2007; Pratt and Govan 2011). This lack of attention is due partly to a lack of understanding of the full *economic value* of marine and coastal ecosystem services (TEEB 2012).

The *economic contribution* of biodiversity and ecosystem services to the wellbeing of Pacific Islanders is understated for a variety of reasons including:

- Substantial resource-based *economic activity* exists outside of formal markets (e.g. subsistence based)
- Customary resource tenure arrangements that poorly reflect individual economic decisions and pricing in markets
- Government agencies in the region typically have relatively low capacity in environmental economics and *green national accounting*
- Many countries of the region are relatively young and/or have lacked continuity in governance, which has contributed to a lack of long-term data and analysis of ecosystem stocks and service flows at the national level
- Many countries of the region have a history of a two-tiered economy; one export and expatriate-led and the other traditional village-based and subsistence-oriented. Both tiers, however, are largely dependent on the same resource base. Planning and policy has generally struggled to address the interest of both dimensions of resource-based economic development at the national scale.

Identifying the *economic value* of marine and coastal ecosystems and taking these findings into account in national planning processes can help create incentives for more effective protection and sustainable use of marine resources. This, in turn, will help to sustain the benefits that people derive from those marine and coastal ecosystems.

1.3 Purpose and objectives

This marine ecosystem services valuation (MESV) study aims to contribute to national development plans and marine resource management policies and decision-making.

The principal objective of the MESV is to identify, quantify and, as far as possible, value in monetary units the most relevant services received from marine and coastal ecosystems in the Cook Islands. This provides a national assessment of the human benefits derived from marine and coastal ecosystems. A comprehensive survey of the current state of knowledge and priority knowledge gaps is the first step towards accounting for marine natural capital and a *baseline* on which more detailed valuation studies could be built. The information provided in the report can be used to guide, design and develop marine resources management plans, policies, assessments, legislation and tools, such as marine protected areas (MPAs) and environmental impact assessments (EIAs).

This economic valuation is intended to enhance ecosystem-based marine and coastal resource management. In doing so, this will lead to more resilient coastal and marine ecosystems, more effective conservation of marine biodiversity, and to contribute to climate change adaptation and mitigation, as well as securing and strengthening local livelihoods and food security.

1.4 Description of the scope and boundaries of analysis

The Cook Islands is a Pacific Island country, with a very small land area but immense marine resource wealth. The Cook Islands' EEZ of nearly 1.96 million km^2 of ocean is 7,000 times larger than the country's land area of just 240 km^2. The country's largest stock of natural wealth lies in the sea, providing numerous real and tangible benefits to Cook Islanders and foreign businesses and consumers.

The Cook Islands terrestrial environment hosts unique geological and biological diversity with many key habitats, providing refuge to various threatened, endemic and migratory species. It forms part of the Polynesia-Micronesia Biodiversity Hotspot (Allison and Eldridge, 2004) where extraordinary levels of biodiversity and endemism are coupled with high levels of threats and the highest rate of species extinction on Earth (Steadman, 1995) with just 21% of the region's original vegetation remaining in pristine condition (CEPF, 2007). The southern Cook Islands biomes were recognised as one of the Global 200 priority ecoregions for global conservation.

The marine environment of the Cook Islands has ecosystem diversity between the high islands in the south with shallow lagoons and fringing reefs, and atolls in the northern group characterized by large, deep lagoons encircled by coral reef. Other notable marine ecosystems include seamounts, sea beds, and the open ocean water columns. Some marine species present are threatened with extinction; there are 61 globally threatened species as well as many endemic species that are locally threatened. There are 25 threatened coral species, 8 threatened fish species, 3 marine turtle species and 3 threatened whale species.

This study provides a national-scale assessment of the economic value of ecosystem services and biodiversity of the Cook Islands marine environment. The geographic scope of the analysis is national in order to provide the broadest potential relevance to policy and decision-makers. The assessment focuses on the value of ecosystem services in the year 2019 and provides information on trends over time where possible. The global Covid-19 pandemic that started in 2020 has had significant impact on the use and value of some marine ecosystem services in the Cook Islands. In particular, the number of tourist visitors, and consequently the value of the coastal environment to tourism, has dropped dramatically in the past year. The value of fisheries has also been affected by the huge decrease in demand by tourist visitors. On the assumption that the use of marine ecosystem services is likely to rebound to pre-Covid levels when the pandemic is brought under control, this study does not provide values for 2020 and considers the 2019 values to be a better representation of ecosystem service value for the purposes of long term decision making.

1.5 Report outline

This report provides details of the country-specific context in which the economic valuation was conducted, and explains the methodological framework for the analysis. The specific methods applied in the report are discussed briefly (see Salcone et al. 2016 for detailed methods). This report depends primarily on existing data and reports, synthesising this information and drawing conclusions where possible. It also presents the results of a household survey conducted to gather information on resource harvesting, recreational activities and willingness to pay for marine conservation. The report also identifies important knowledge gaps and makes recommendations for future research.

The report describes and quantifies the Cook Islands' marine and coastal resources, and where possible, estimates their *economic value*. Ten key marine ecosystem services are evaluated in detail: subsistence fishing, commercial fishing; trochus; pearls; sand and coral aggregate; seabed minerals; coastal protection; international tourism; domestic recreation; and non-use values related to the conservation of marine ecosystems. Additional services explored include cultural and traditional values associated with the sea, carbon sequestration, and research and education.

The Cook Islands' institutions are described in Section 2, followed by an overview of national policies, objectives, and initiatives, which could potentially use information about the human benefits of marine ecosystems provided by this report. The TEEB initiative and global framework for ecosystem service valuation are presented in Chapter 3. Chapter 4 provides an overview of economic valuation literature relevant to PICTs; data collection and technical valuation methods are explained in Chapter 5.

The core of this report is Chapter 6 — the results of an economic assessment of marine and coastal ecosystem services. The first component of each subsection of the results, **Identify**, is a clear identification of how each natural marine and coastal ecosystem provides benefits to humans. That is, how *ecosystem functions* become *ecosystem services*. The second component, **Quantify**, is a review of data that quantitatively describe the magnitude of each ecosystem service. Early in the project it was established that a lack of comprehensive and reliable data would substantially limit the depth and breadth of economic valuation of ecosystem services. In response to this obstacle, an analysis of data gaps is a core focus of this national report. The third component, **Value**, presents an estimate of the *economic value* of the ecosystem service as much as the data available allow.

The Cook Islands experience annual variability in the magnitude of benefits from marine and coastal ecosystems, particularly with regard to commercial fisheries. In some instances, due to variations in harvests and changes to the health of the ecosystem, an annual value of the ecosystem service is hardly relevant. These and methodological and data issues are discussed in the **Uncertainty** section. In the **Sustainability** section, the report indicates whether current resource uses are sustainable, that is whether the natural benefits can be expected to continue, to increase, or to decrease with current practices. The values of different *ecosystem services* may accrue to few or many, nationals or foreigners, businesses or consumers. In order to understand the incentives that motivate different resource use patterns, it is important to consider who receives the benefits from the various marine and coastal ecosystems services in the Cook Islands. The **Distribution** section for each ecosystem service describes the distribution and considers equity of existing ecosystem benefits.

The results for each ecosystem service are synthesised in Chapter **Error! Reference source not found.** together with recommendations and suggestions for how this information could be used. Since economic information is commonly plagued by misinterpretation, an explanation of the caveats and limitations of this research as well as disclaimers about how this information should not be used are presented in Chapter 8. Chapter 9 makes recommendations for areas for further research.

2 Context

2.1 Geographic context

The Cook Islands is a country located in the South Pacific comprising an archipelago of 15 islands. The southern group of islands is made up of volcanic islands and atolls, while the northern Cook Islands are mostly atolls (de Scally, 2008). Three of the islands are uninhabited, i.e. Manuae, Suwarrow and Takutea (Solomona et al., 2009). The total land area is 240 km^2 with an Exclusive Economic Zone (EEZ) of more than 1,960,000 km^2.

The coastal environment of the Cook Islands comprises lagoons and reefs that provide habitat for a multitude of marine species. These resources form the basis of the livelihoods for many of the inhabitants who practice subsistence fishing (55% of the population – Solomona et al., 2009). Artisanal fishing, where fishers sell to local markets, accounts for 35% of fish harvested; whereas commercial fishing represents 10% of the fishery sector (Solomona et al., 2009).

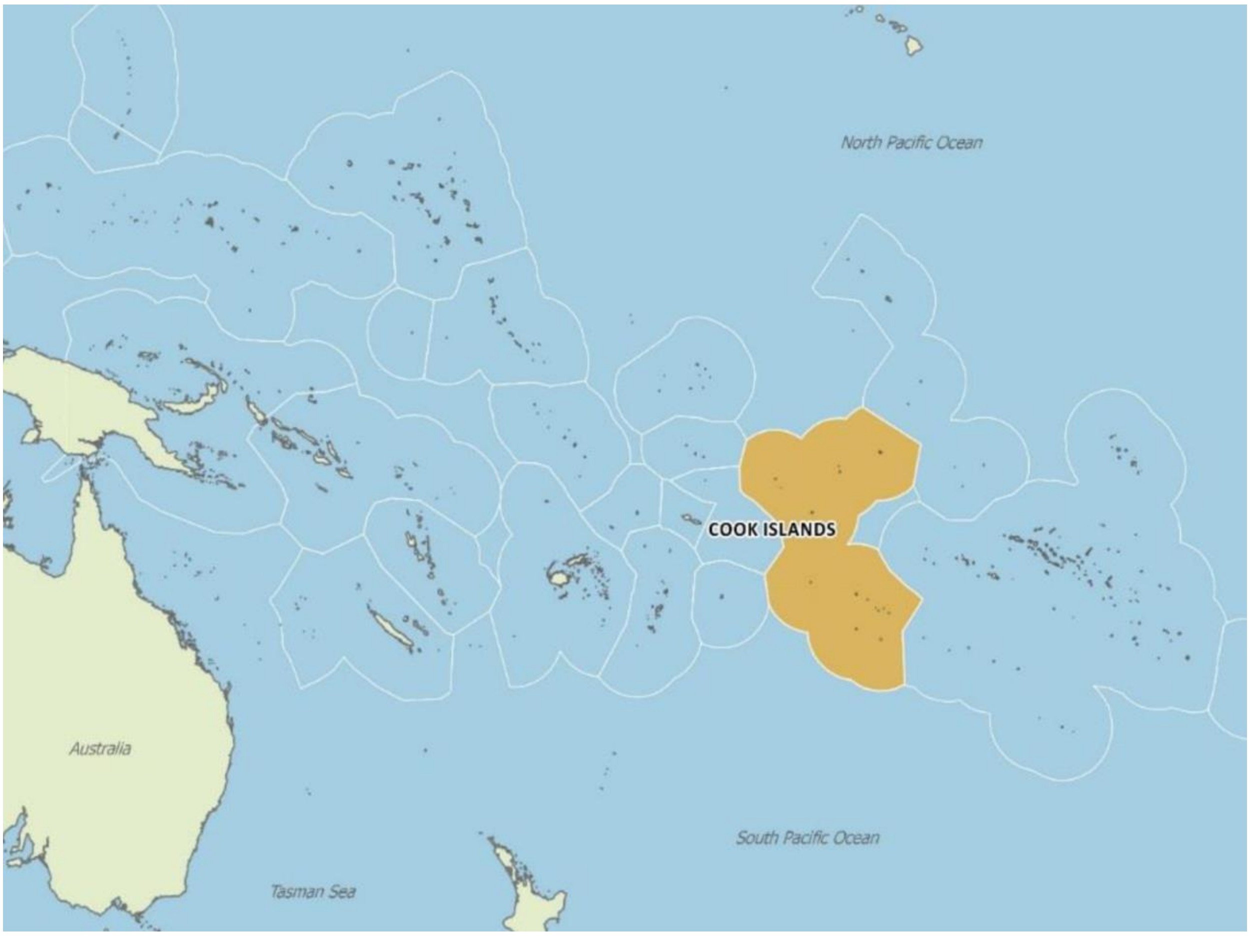

Figure 1. Geographic location of the Cook Islands (source: CISO 2018)

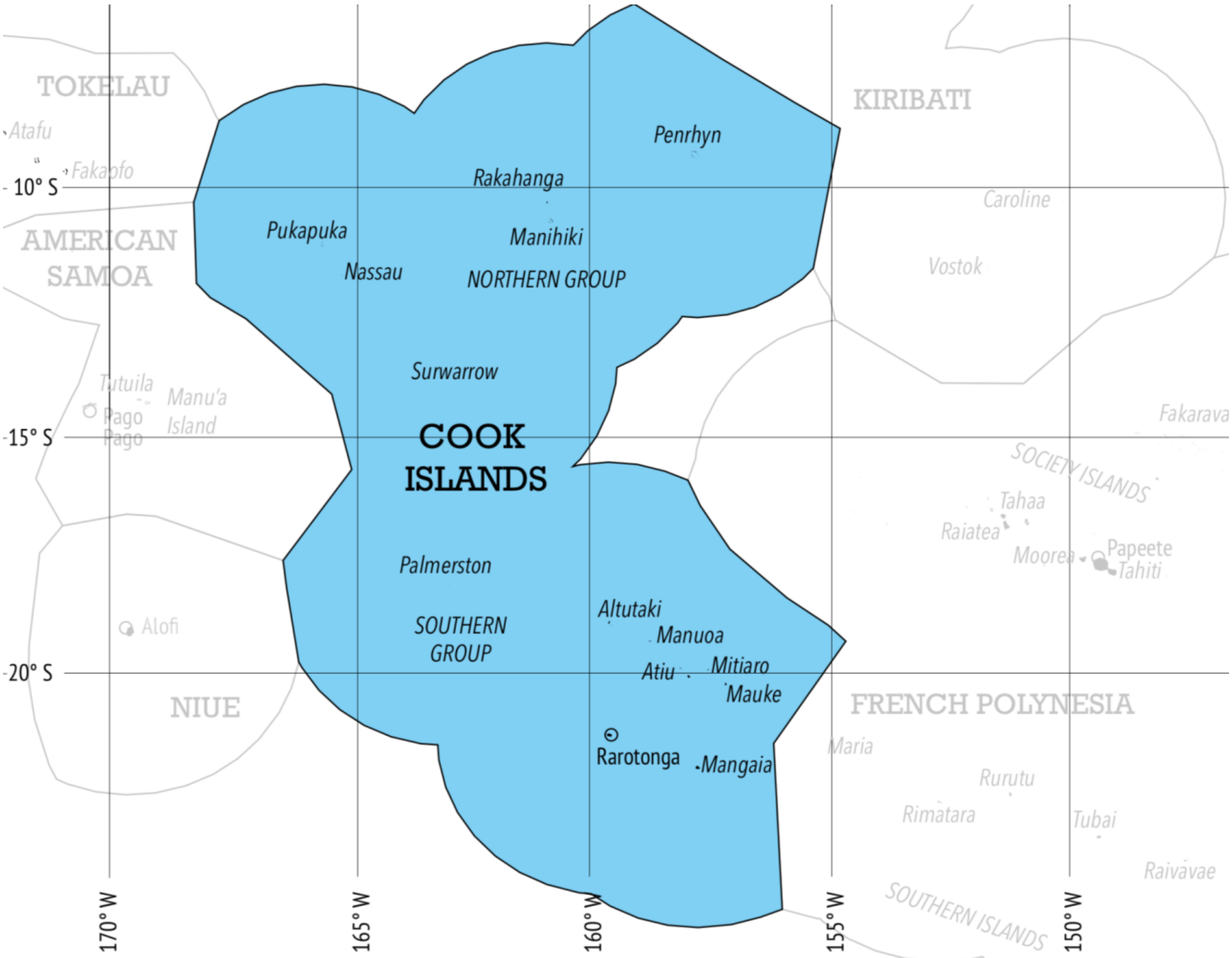

Figure 2. Geographic location of the Northern and Southern groups of the Cook Islands (source: Gillett 2016)

2.2 Demographic and economic country profile

The Cook Islands had a total population of 17,434 (residents and non-residents) as recorded in the 2016 Census of Population and Dwelling (CPD). This was a 2% decrease relative to the population recorded by the 2011 CPD. Approximately 75% of the population reside on Rarotonga, which is located in the Southern group and is the administrative and commercial centre of the Cook Islands. In terms of age distribution, 27% of the resident population was younger than 15 years, and 15% were older than 59 years. The proportion of the population aged 15–59 was 58% (CISO and SPC, 2018).

The Cook Islands gross domestic product (GDP) in 2019 was NZD 575.4 million (MFEM, 2020a). The country's economy is highly dependent on tourism, with approximately 169,000 visitors annually, mainly from New Zealand. The second major source of income for the Cook Islands is from licensing offshore fishing (Solomona et al., 2009). Other exports include black pearls. In addition, the marine environment is a large component of the informal economy (Wakefield et al., 2018) and provides Cook Islanders with a wealth of opportunities for recreational and cultural activities. A future economic activity in the marine environment that is currently being considered is the extraction of seabed minerals. The Cook Islands are recognized as one of the most promising areas for deep sea mining located outside of the Clarion Clipperton Zone (McCormack, 2016; Weaver et al., 2018).

The average income across all residents is NZD 16,300, with nearly 50% of the population earning less than NZD 10,800 per year. Residents of the Northern Group islands have lower average annual income of NZD 8,600, with 54% of the population making less than NZD 5,300 (SPC, 2016).

The official currency used in Cook Islands is the New Zealand dollar (NZD) and all monetary values provided in this report are in NZD.

2.3 Institutional context and policy context

The *Marae Moana Act 2017* established the Marae Moana (also known as the Cook Islands Marine Park – CIMP) in the waters of the Cook Islands and provides for its integrated management. Part 3 of the Act covers policy and spatial planning and specifies that regulations must be developed and in place to guide development of marine spatial plans (MSPs). The Act provides for two types of MSPs: a national Marae Moana spatial plan (NMMSP) and individual island marine spatial plans.

The Act defines the NMMSP planning area as being 12 nautical miles (nm) from the baseline to the 200 nm mark of the Exclusive Economic Zone (EEZ). There is no specific legal definition of the geographic extent of IMSPs, however, it can be inferred from the Act that they cover internal waters (where these exist), and the territorial sea (from the baseline out to the 12 nm mark). Section 24 of the Act further establishes a marine protected area (MPA) of 50 nm around all 15 islands. Mining and large-scale fishing are prohibited in these areas (*Marae Moana Act 2017*).

Marine Spatial Planning (MSP) is a practical way of balancing the demands of human activities with the need to maintain the health of the ecosystems on which those activities depend. This is especially important in PICTs where approximately 98% of the area under each nation's jurisdiction is ocean (Halpern et al., 2008). Marine ecosystems are known to be in decline, mostly due to human activities, but there is recognition that it is possible to manage human activities to minimise many of these impacts. MSP involves an inter-sectoral and participatory public process of identifying, balancing and achieving economic, social and ecological objectives in a transparent and organised way (Ceccarelli et al., 2018).

The Cook Islands National Sustainable Development Plan (NSDP) 2016-2020 is the national policy vehicle for implementing and achieving the global sustainable development goals (SDGs) (CPPO, 2016). The NSDP provides a scorecard for development, rather than an explicit plan. It also articulates key performance indicators for the broad national policy suite to represent national development. These indicators underpin the sixteen development goals which are aligned to commonly identifiable sectors. Goal 12 specifically addresses the sustainable management of oceans, lagoons and marine resources. Together they represent a holistic, objective scorecard for the development of the Cook Islands. They are closely aligned to regional and international commitments such as the Pacific Regional Framework and the Global Sustainable Development Goals. The next iteration of the NSDP (NSDP 2020+) is due to be released in April 2021.

2.4 Related projects and initiatives

Sustainable use and conservation of marine and coastal biodiversity are priority action areas of the Strategic Plan of the Convention on Biological Diversity (CBD). The Cook Islands have expressed their commitment to the implementation of the extensive CBD resolutions on the conservation and sustainable use of marine and coastal biodiversity, including:

- Implementing actions outlined in the Cook Islands' NBSAP
- Contributing to the CBD Programme of Work on Protected Areas, especially to attainment of Aichi Target 11
- Assisting with implementation of the CBD Programme of Work on Island Biodiversity in accordance with the CBD COP 11 decision.

Beyond the CBD, the Cook Islands has other commitments, interests and projects that this report can contribute to, including:

- Pacific Regional Environment Programme Strategic Plan 2017–2026
- The Pacific Islands Regional Oceans Policy (PIROP)
- Pacific Oceanscape Framework (FPO)
- Framework for Resilient Development in the Pacific (FRDP)
- System of Environmental Economic Accounts (SEEA) and in particular the Experimental Ecosystem Accounts developed by the UN Statistics Division.
- Sustainable Development Goals (SDGs) and in particular SDG 14 Life Below Water
- United Nations Convention on Law of the Sea (UNCLOS)
- UN Fish Stocks Agreement
- Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (WCPF Convention)
- Convention on Wetlands (RAMSAR)
- International Coral Reefs Initiative
- United Nations Framework Convention on Climate Change (UNFCCC)
- Framework for Nature Conservation and Protected Areas in the Pacific Islands Region 2014-2020.
- Restoration of Ecosystem Services against Climate Change Unfavourable Effects (RESCCUE).
- The Economics of Ecosystems and Biodiversity (TEEB), and in particular the TEEB4Coasts initiative.

3 Conceptual framework

The principal objective of the MESV is to identify, quantify and, as far as possible, value in monetary units the most relevant services received from marine and coastal ecosystems in the Cook Islands. This is done to provide decision-makers and policy-makers at all levels with information about the economic value that people derive from marine and coastal ecosystems. For this reason, significant effort was made to conduct the work collaboratively, and with close interaction with key government and non-government stakeholders as well as technical staff in the Cook Islands.

3.1 Definitions

Ecosystems

An *ecosystem* is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Natural ecosystems have varying attributes (e.g. particular species of plants and animals) and perform various functions (e.g. photosynthesis, chemical and nutrient cycling). Many of these attributes and functions benefit human activities, communities, and industries.

Ecosystem services

Ecosystem services are the benefits humans receive from the natural attributes and functions of ecosystems. These benefits could be material goods such as timber or fish, or regulating services such as the treatment of human waste and carbon sequestration.

The value of marine (and other) ecosystem services to people is often not visible in markets, business transactions or in national economic accounts. Their value is often only perceived when the services are diminished or lost. Assigning monetary values to marine ecosystem services to reflect their importance to Cook Islanders is a powerful tool for making these benefits visible and improving their wise use and management. The process of assigning monetary values to ecosystem services that benefit people is called *economic valuation*.

In assessing and comparing ecosystem services, sometimes there are trade-offs to be made between different ecosystem services. For example, mining a coral reef for building materials will likely diminish its value as a source of food from fishing. Other ecosystem services can be complementary, for example the coastal protection value of coral reefs and their tourism value from diving or snorkelling.

Economic value

Economic value refers to the quantified net benefit that humans derive from a good or service, whether or not there is a market and monetary transaction for the goods and services. *Economic value* needs to be distinguished from *economic activity* (also known as financial or exchange value), which is a measure of cash flows and is observed in markets[3]. While *economic activity* from market transactions is often used to calculate *economic value*, *economic activity* is not in

[3] Analysis of *economic activity* often focuses on 'multiplier effects', that is, the proportion of cash flows from one industry that spill over in to other industries due to inter-industry linkages.

and of itself a measure of human benefit. *Economic activity*, however, is an interesting measure[4]. The number of formal-sector jobs and the level of capital investment are closely related to *economic activity*, and this is of interest to the public, civil servants and policy-makers. This report focuses on measuring *economic value*. Caution must be taken not to compare *economic activity* to *economic value*. Although both can be represented in dollars per year, they are different measurements of benefits. It is also worth noting that Government revenue from taxation on specific economic sectors or activities is not treated as part of their economic value. Public tax revenue and spending is simply a redistribution of economic value. In national assessments, however, it is relevant to record public revenue from taxation of non-national citizens (e.g., tourists) or businesses (e.g., fishing vessels), which represent redistribution of value from non-nationals to nationals.

Consumer and producer surplus

In general, the analysis in this report is based on the microeconomic concepts of *consumer* and *producer surplus*. *Consumer* and *producer surplus* are net measures; they measure the difference between the benefits and the costs of a particular good or service. *Producer surplus* is the benefit received by businesses, firms, or individuals who sell a good or service (the difference between the price that a producer is able to sell their goods for in the market compared to the minimum price they would be prepared to accept, which is computed as the surplus between the price they receive and their cost of production). *Consumer surplus* is the benefit received by individuals who purchase or freely enjoy a good or service (the difference between the benefit they obtain from consuming a good/service and the price paid for it, which is computed as the surplus between a consumer's maximum willingness to pay for a good and its market price). For market transactions, *producer surplus* is synonymous with *value-added* or *profit*.

Willingness-to-pay and willingness-to-accept

Benefits are quantified by an individual's *willingness-to-pay* (WTP) or a business's *willingness-to-accept*, or rather, how much money an individual or business would willingly trade for providing or receiving a good or service. The difference between consumers' maximum WTP and what they actually pay is the consumers' surplus from the transaction. Consumer WTP is represented graphically as a demand curve.

Total economic value

The *total economic value* (TEV) of an ecosystem service includes all of the net benefits humans receive from that ecosystem service. *TEV* is a quantification of the full contribution ecosystems make to human wellbeing. *Total economic value* includes market and non-market values (i.e. *direct use value*, *indirect use value*, and *existence*, or *non-use*, *value*) and therefore represents the full benefit humans receive from *ecosystem services*.

In practice, *TEV* is nearly impossible to estimate because the data required to do so are rarely available. For example, fisheries resources offer benefits to those who harvest and sell seafood products (producers), as well as those who consume seafood products (consumers). The *TEV* of the fishery is a sum of the producer and consumer benefits. However, consumer benefits are

[4] Gross Domestic Product (GDP), recorded through the System of National Accounts (SNA), is a measure of *economic activity*. The UN Statistics Division has recently published guidance for a System of Environmental-Economic Accounts (SEEA), which provides an accounting framework that is consistent, and can be integrated, with the structure, classifications, definitions and accounting rules of the SNA, thereby enabling the analysis of changes in natural capital, its contribution to the economy and the impacts of economic activities on it. It should be noted, however, that this system is restrictive in terms of the types of services and values that can be assessed.

difficult to estimate, and, in the case of export products, they accrue to individuals distant from the natural resource. Producer benefits alone are commonly used to estimate the value of fisheries, as is done in this report. It should be noted, however, that these estimates are a lower-bound value and do not accurately represent *TEV*.

Further definitions can be found in the Glossary (Appendix I: Glossary).

3.2 The Economics of Ecosystems and Biodiversity (TEEB)

This study follows the approach for assessing ecosystem services developed by the TEEB initiative (The Economics of Ecosystems and Biodiversity; www.teebweb.org). The TEEB approach comprises six steps:

1. Specify and agree on the relevant policy issues with stakeholders
2. Identify the most relevant ecosystem services
3. Define information requirements and select appropriate methods
4. Quantify, then value, ecosystem services
5. Identify and appraise policy options and distributional impacts
6. Review, refine and report.

It is anticipated that this report will provide a platform from which to identify priority actions — in terms of national policy development, national and watershed-scale data collection, regular analysis, planning and outreach — that better incorporate *ecosystem stocks*, *ecosystem service flows* and values into ongoing national discussions and policy processes (Steps 5 and 6).

3.3 Applications of marine ecosystem service valuation

There are three main categories of applications of marine ecosystem service valuation:

1) to enable rational decision-making, via cost-benefit analyses or other analyses of the trade-offs in management decisions;

2) as a technical tool to set prices for protecting resources or compensation for ecosystem damage; or

3) as general information, to raise awareness about the human benefits of healthy ecosystems and support policy and governance that manages resources from a social equity perspective (Mermet et al. 2014).

The third application can lead to full integration of the benefits of ecosystems into national accounting (natural capital accounting). National-scale ecosystem service valuation is applicable mostly to this third use — i.e. general information for planning and advocacy.

4 Literature review

This section briefly reviews ecosystem service valuation studies that have been conducted in the Cook Islands and other Pacific Island Countries and Territories (PICTs), drawing on existing surveys of the literature (Lal and Holland, 2011; Jungwiwattanaporn et al. 2015; Brander, 2019).

In total, Brander (2019) identified 64 studies that estimate values for ecosystem services in PICTs. The reference to each study is included on the map in Figure 3 to indicate the number of valuation studies for each country or territory. It is evident that some locations have been the subject of much greater research effort than others, with Hawaii and Fiji having a long history and many ecosystem service valuation applications. The literature survey found four valuation studies have been conducted for the Cook Islands, which are briefly summarised below.

Regarding the ecosystem services that have been valued in PICTs, the existing literature spans provisioning, regulating and cultural services (see Figure 4).

The provisioning service that has received the most attention is the input of coastal and marine ecosystems to commercial fisheries, with over half (35) of the reviewed studies addressing this service. Conversely, non-fisheries provisioning services such as timber and non-timber forest products have received very limited attention. Given that most valuation studies focus on marine ecosystems, it is not surprising that these predominantly terrestrial services are not well covered in the existing literature.

Regarding regulating services, the role of coastal ecosystems, particularly coral reefs and mangroves, in protecting property and infrastructure from storm surges and flooding has also been valued in a large number of studies (22). The value of coastal ecosystems for climate regulation has been valued in a relatively small set of studies under the MACBIO project (http://macbio-pacific.info/). These five country studies for Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu use a consistent method to value the carbon stored in mangroves.

Cultural services have been valued in a large number of studies. The direct use of coastal ecosystems for tourism (23) and recreation (11) has been widely studied. The non-use value placed on conservation of biodiversity has also been estimated in a number of studies (10). For example, O'Garra et al. (2009) used the contingent valuation method to estimate the non-use value of coral reefs to households living on the coral coast in Fiji to be US$ 107/household/year (2006 price levels) and Marre et al. (2015) used a choice experiment to estimate use and non-use values for coral reef services, and found that non-use values compromised between 27-41% of total willingness to pay. Other cultural services such as aesthetic enjoyment, importance to spiritual practices and cultural identity have received less attention, although there are a number of studies that apply qualitative research methods to examine these (e.g., Pascua et al., 2017). No studies were found that estimate the use or non-use value of specific endemic species.

A further observation on the coverage of ecosystem services in the literature is that existing valuation studies have generally addressed multiple services and in many cases aimed to estimate the total economic value of the ecosystem resource (i.e. estimate the value of all relevant ecosystem services) – see van Beukering et al. (2006), Salcone et al. (2015), and Conner and Madden (2017). This comprehensive perspective is useful to inform a holistic approach to resource management that aims to safeguard and deliver a wide range of services rather than simply focusing on a few. Estimating the value of bundles of services also has the potential to identify trade-offs between services (e.g. between fisheries and tourism).

The methods that have been used to measure and quantify economic values for ecosystem services are varied, and the resultant value estimates can rarely be compared directly; rather, they should be evaluated on a case-by-case basis. Readers interested in learning more are encouraged to read the MACBIO guidance manual on economic valuation of marine and coastal ecosystem services in the Pacific (Salcone et al., 2016).

There are several regional studies on the value of ecosystems and ecosystem services in PICTs. A general assessment of the value of Pacific Island ecosystems conducted by economists at IUCN in 2010 estimated that coral reefs had a total economic value of US$ 4.11 billion or US$ 79,000/km2/yr (Seidel and Lal 2010). This value was based on an extrapolation from Pacific case study estimates. Direct use values made up US$ 2.22 billion of this estimate, and indirect and non-use values made up US$ 1.40 billion. Direct use values included fisheries, coastal protection and tourism and recreation; indirect values included existence and biodiversity values (Seidel and Lal 2010). The same authors estimated that mangroves contributed a total economic value of US$ 4.20 billion or US$ 593,726 per square kilometre per year in the 22 Pacific Island States and Territories. This value included US$ 2.48 billion from direct use values (subsistence and artisanal fishing, shoreline protection, fuelwood production) and US$ 1.71 billion from indirect and non-use values (cultural and social values, existence values) (Seidel and Lal 2010).

For fisheries, there is a series of regional studies that estimate the combined value of fishery and aquaculture production, including subsistence fisheries, local commercial fisheries, and foreign-based commercial fisheries in nearshore and open-ocean habitats (Gillett and Lightfoot, 2001; Gillet, 2009; Gillet 2016). These studies report fisheries production, values, employment, exports, contribution to GDP, Government revenue, and consumption for each of 22 PICTs, including the Cook Islands. The results from Gillet (2016) are used to value subsistence and commercial fisheries in this report.

Hajkowicz and Okotai (2005) estimate the costs of watershed pollution on Rarotonga, including the impact to fisheries in the lagoon. The estimated value of fish stocks in the lagoon lost due to watershed pollution is NZ$ 534,000 per year. Such costs can be considered as the potential benefits of improved watershed management.

Passfield (1997) examines the monetary value of inshore marine resources for Tongareva (also known as Penrhyn) in the Northern Cook Islands. Tongareva is an atoll with a large lagoon, but located more than 1,000km from the only significant market in the Cook Islands. As such it has no commercial fishery, but the subsistence fishery was valued at NZ$ 475,000 per year with an additional NZ$ 53,000 per year of seafood exported. In total the value of harvested fish is estimated to be equivalent to 27% of per capita cash income of Tongarevans.

Rongo and van Woesik (2012) examine the socio-economic consequences of ciguatera poisoning in Rarotonga, which had experienced the highest rates of ciguatera poisoning in the world. The study used information on protein consumption collected through a household survey to show that ciguatera poisoning resulted in a halving of the per-capita fresh fish consumption, from 149 g/person/day in 1989 to 75 g/person/day in 2006. As a consequence, the consumption of alternative proteins, particularly imported meats, increased during the same period. The gross value of harvest loss of reef fish was estimated to be approximately NZ$ 750,000 per year and the approximate costs associated with dietary shifts amounted to NZ$ 1 million per year.

Conner and Madden (2017) estimate the economic value of ecosystems and associated ecosystem services in the Cook Islands as an input to the revision and update of the National Biodiversity Strategy and Action Plan (NBSAP) for the Convention on Biological Diversity (CBD).

The study covers terrestrial and marine ecosystems and a wide range of ecosystem services including provisioning services (agriculture, medicinal plants and flowers, forest products, fisheries, pearls and trochus), regulating services (catchment protection, greenhouse gas regulation) and cultural services (tourism, non-use values). Conner and Madden (2017) estimated the present value of Cook Islands ecosystem services to be NZ$ 2.4 billion over a 30-year time horizon using a discount rate of 2.65%.

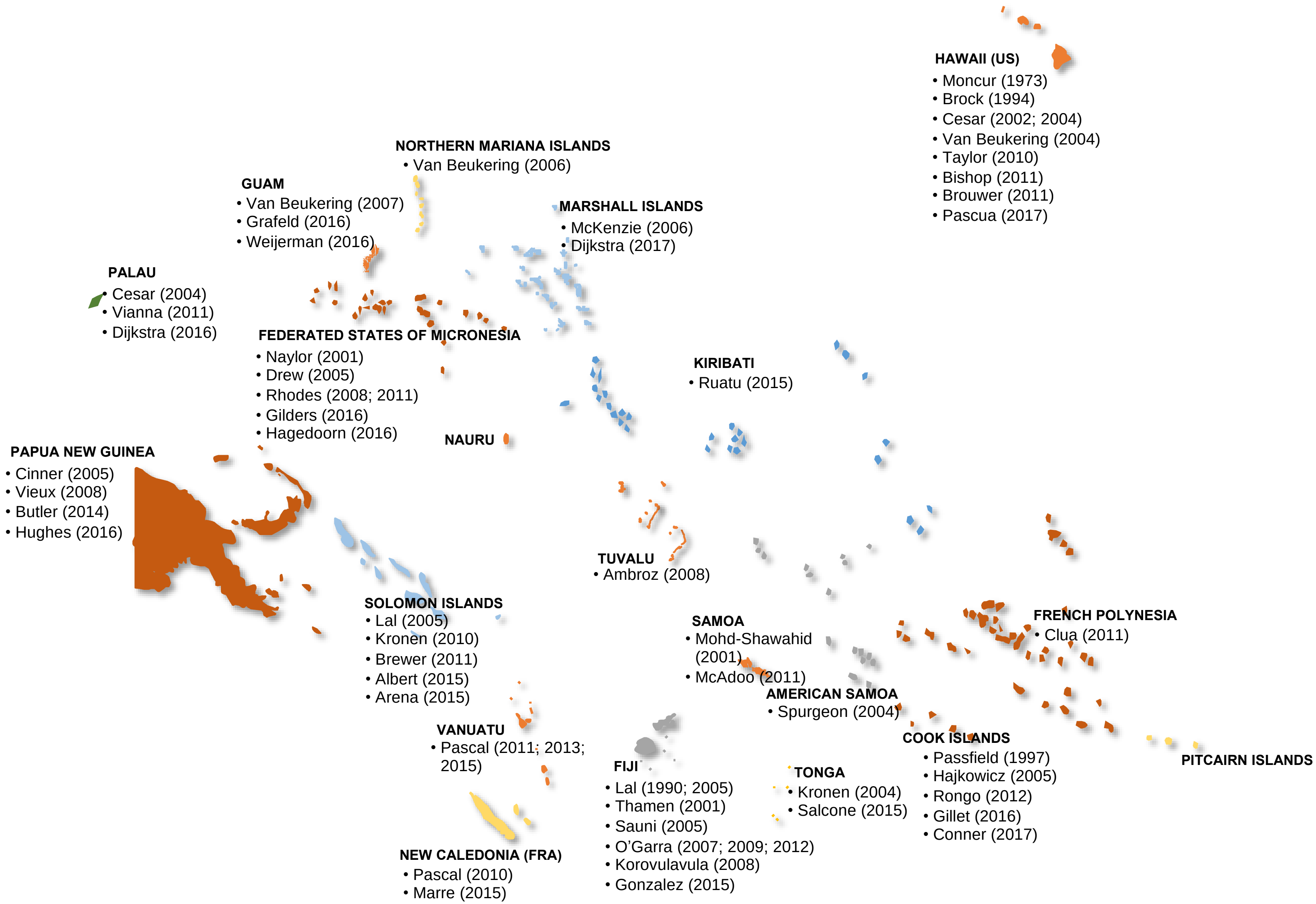

Figure 3. Ecosystem service valuation studies for Pacific Island Countries and Territories (adapted from Brander, 2019).

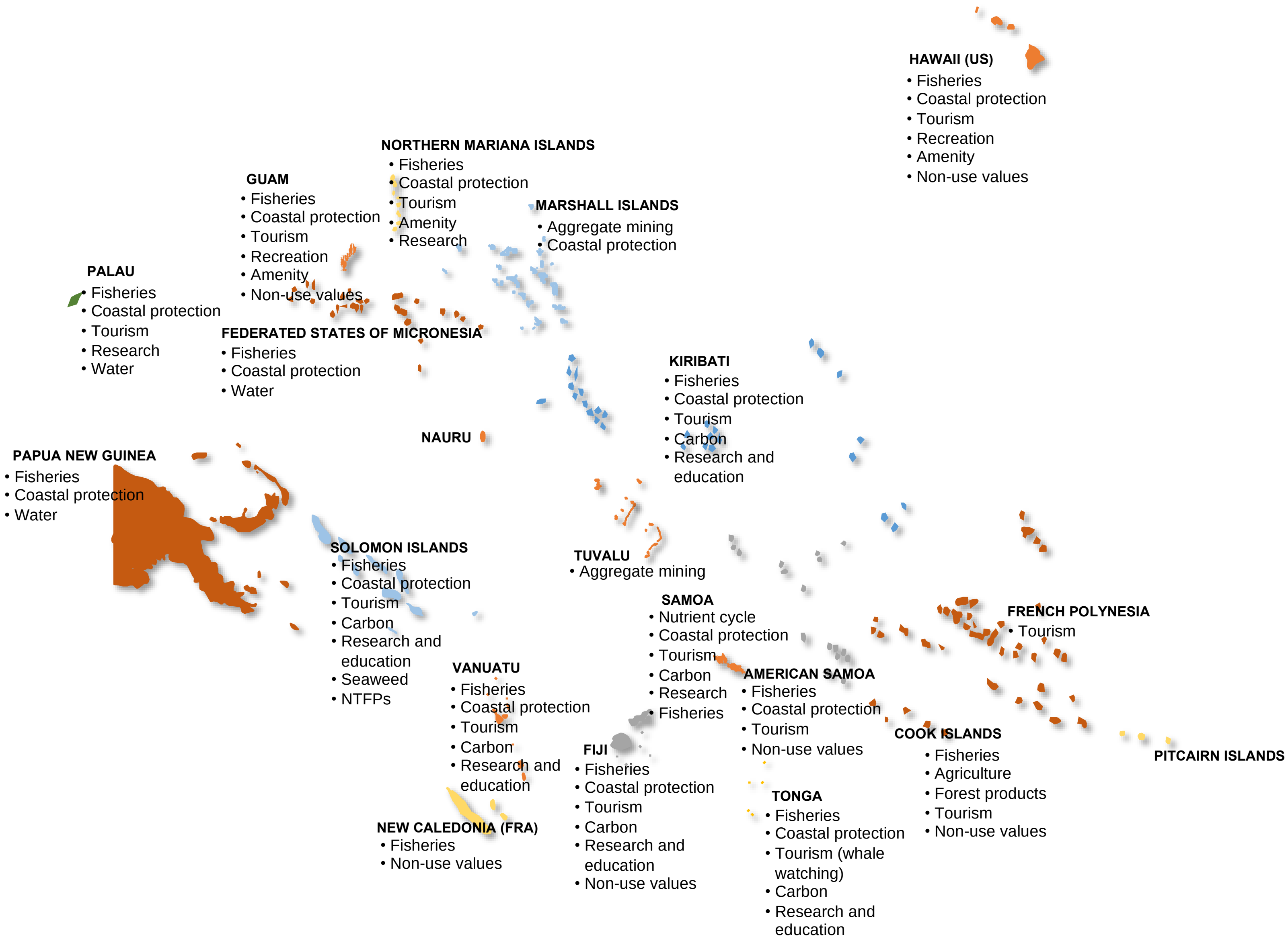

Figure 4. Ecosystem services valued in Pacific Island Countries and Territories (adapted from Brander, 2019).

5 Methods

The methods and data requirements for estimating the value of marine and coastal ecosystem services are provided in Salcone et al. (2016), which is a methodological guidance document created in consultation with country-based research teams and other Pacific resource economists under the Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project[5]. Specific details of methods applied in this report are presented below or in the relevant sections of the report. In addition to the methods described in Salcone et al. (2016), which mainly rely on secondary data, the present study used a household survey to collect primary data on resource harvesting and cultural uses of the marine environment. The household survey was also used to conduct a choice experiment valuation of reef fish abundance, water quality for recreation, and marine biodiversity. The household survey is described in section 5.3 and the choice experiment is described in section 5.4.

5.1 Overview

This study identified the following key marine and coastal ecosystem services that are described and valued in this report:

1. Subsistence fisheries
2. Commercial fisheries
3. Trochus
4. Pearls
5. Sand and coral aggregate
6. Seabed minerals
7. Coastal protection
8. Tourism
9. Recreation
10. Existence and bequest values

Marine and coastal ecosystems provide many more ecosystem services than the ten explored here. These ten ecosystem services were identified as nationally important, potentially quantifiable with existing data, and amenable to policy intervention or private action.

Where sufficient data are available, ecosystem service valuation represents *producer* and/ or *consumer surplus* and includes market and non-market values for direct and indirect ecosystem services (see Section 3.1 for further information). Where data do not exist to implement the most appropriate methods, the next best possible ecological-economic analysis has been conducted. This may include qualitative descriptors of values or references to other locations with data on the identified values. Gaps in data and previous research are partially offset with the authors' judgment based on economic theory.

[5] http://macbio-pacific.info/

Unless otherwise stated, all monetary values have been converted to 2020 New Zealand dollars (NZD). Values recorded at pre-2020 price levels were converted to 2020 price levels using the World Bank Consumer Price Index (CPI) for the Cook Islands. Where appropriate, international seafood products were inflated using the Food and Agriculture Organization (FAO) Fish Price Index.

5.2 Secondary data sources

To a large extent the study makes use of existing sources of data to analyse ecosystem service values and to identify data gaps. Secondary data sources from the Government of the Cook Islands were the 2016 Census, the 2015-2016 Household Income and Expenditure Survey (CISO and SPC, 2018), and GDP and migration statistics from the Ministry of Finance and Economic Management (MFEM, 2020a; 2020b). The Ministry of Marine Resources provided data records for fisheries exports; additional fisheries data were obtained from reports by the SPC (Gillett, 2016). Other data were obtained from academic studies and project reports. The validity and accuracy of these secondary data, which vary among sources, is described following the identification, quantification, and valuation of each ecosystem service.

As far as possible, government staff and other relevant parties in the Cook Islands worked with the authors to answer questions, supply information and data, and to identify data gaps for this report. Due to travel restrictions in response to the Covid-19 pandemic, the lead consultant was not able to conduct any site visits or in-person consultations. Communications between members of the research team, stakeholders and data providers were predominantly by email or video call.

5.3 Primary data sources

The study conducted two surveys to collect primary data: 1. Stakeholder consultation survey to identify key ecosystem services to be addressed in Marine Ecosystem Service Valuation (MESV); 2. Household survey to collect information on the use and value of selected ecosystem services. The design and implementation of these surveys are described in this section; the results are described in section 6.

An initial consultation of stakeholders in the Cook Islands was conducted during the period 7-26 August 2020 by email and through an online questionnaire (see Appendix II). The purpose of this initial stakeholder consultation was threefold: 1. To inform stakeholders of the MESV study; 2. To collect feedback on the ecosystem services included in the study and identify whether any important services were missing; 3. To identify and collect relevant data for the study. In total, 40 stakeholders responded to the survey, representing both public and private sector interests.

A household survey was used to collect information on public use of the marine and coastal environment for: 1. Harvesting of fish and other resources; 2. leisure and recreation activities; 3. cultural practices; 4. conservation of biodiversity, native and migratory species; and 5. public perception of threats to the marine environment.

The survey was administered online and distributed through email contacts and social media during the period 28 October to 13 November 2020. The survey instrument comprised 38 questions and took approximately 17 minutes to complete on average. The full survey instrument is provided in Appendix III.

In total, the survey received 193 responses of which 134 (69%) were complete. A full description of the survey sample is provided in Appendix IV.

5.4 Choice experiment valuation method

To obtain quantitative measures of Cook Islanders' preferences for environmental conservation, we make use of the discrete choice experiment (DCE) method. This stated preference method uses a public survey to elicit the preferences or values of respondents for specified changes in a good or service (Hensher et al., 2005). In the fields of market research and economics the DCE method is widely used to obtain information on public preferences that are otherwise not observable in consumer behaviour (Johnston et al., 2017).

In practical terms, a DCE involves asking survey respondents to make repeated choices between alternative multi-attribute descriptions of a good or service. It is then possible to estimate their relative values of these goods and services by observing the trade-offs that are made between attributes (Hanley et al., 2001). In the present study, respondents were asked to choose between alternative options for conservation of the marine environment that would be funded through hypothetical monthly donations to an administered fund dedicated to marine conservation in the Cook Islands. By analysing the trade-offs that respondents made between conservation measures and the payment, we were able to quantify their willingness to pay for each measure.

The attributes used were:

- Fish and shellfish abundance. The abundance of fish and shellfish that can be caught
- Water quality for recreation. The quality of coastal water that can be used for leisure/recreation
- Marine biodiversity. The diversity of native and migratory marine animal species
- Cost per month. The monetary amount in NZD that the respondent would be willing to pay each month through a donation to an administered fund dedicated to marine conservation in the Cook Islands.

The attribute levels defining each option are represented on choice cards using simple images to provide respondents with a visual support for understanding the differences between options. The representation of attributes and choice cards were tested for comprehension during a pilot survey and found to effectively communicate the provision of each service. An example choice card is represented in Figure 5.

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Figure 5. Example choice card

5.5 Data gap analysis

A major focus of this research effort was identifying gaps and weaknesses in data that prevented the accurate valuation of marine and coastal ecosystem services. The importance of this exercise should not be understated. This report encourages and supports the use of ecosystem service valuation in national planning and policy-making, but in many instances a full *economic value* of the human benefits of ecosystems could not be estimated because of a shortage of ecological or socioeconomic information. These data gaps are described together with the quantification and valuation of ecosystem services in Chapter 6.

6 Results

This section includes the identification, quantification, and where possible, valuation of the Cook Islands' most significant marine and coastal ecosystem services. The first subsection for each ecosystem service, **Identify**, describes the ecosystem service and the relation between the ecological or biological processes of that ecosystem (the *ecosystem functions*) and the human benefits (the *ecosystem services*). This subsection also describes the human activities and livelihoods that are related to the ecosystem service. The second subsection, **Quantify**, describes data that illustrate the magnitude of the service either in monetary units or ecological measures and evaluates data gaps. Where sufficient data could be collected, the third subsection, **Value**, presents the *economic value* of the ecosystem service. The value represents a quantification of human benefits in terms of local monetary currency (NZD).

The **Sustainability** and **Distribution** of ecosystem service benefits is evaluated following the valuation of each service. It is important to understand whether human benefits can be maintained or if they are expected to decrease because of unsustainable resource use or management practices. It is also important to recognise who receives the benefits from the ecosystem, whether it be poor or wealthy households, government, visitors or foreign nationals. The **Uncertainty** of each value estimate is also discussed in this section.

6.1 Identification of key ecosystem services

In the initial consultation survey, stakeholders were shown a list of ecosystem services and asked to score each service in terms of importance to the Cook Islands on a scale 0-5 (with 0 = not at all important; and 5 = very important). The average scores are represented in Figure 6 and show that subsistence fishing, cultural identity, tourism, storm and flood protection, research and education, existence of biodiversity, wastewater filtration and recreation are identified as the most important ecosystem services (average scores over 4). On the other hand, seabed minerals, saltwater filtration, trochus harvest, and sand and coral aggregate were seen as less important services (average scores less than 3).

Respondents were also asked to note any important ecosystem services not listed, which yielded several suggestions including the use of the sea for transportation, kinetic energy potential, genetic material, regulation of microclimate and regulation of shoreline erosion. Several threats and other issues were also raised including deforestation, plastic pollution, the functioning of the ra'ui system, the importance of seamounts, pest eradication, and solid waste management.

Regarding threats to the marine environment, respondents to the household survey were asked to indicate their level of concern for a range of threats on a 1-5 Likert scale. The results are summarised in Figure 7. Generally, the level of concern is high but there is evidently higher concern regarding plastic waste and sewage and waste water. It is notable that seabed mineral exploration is of lowest concern, perhaps due to the framing on 'exploration' as opposed to actual extraction.

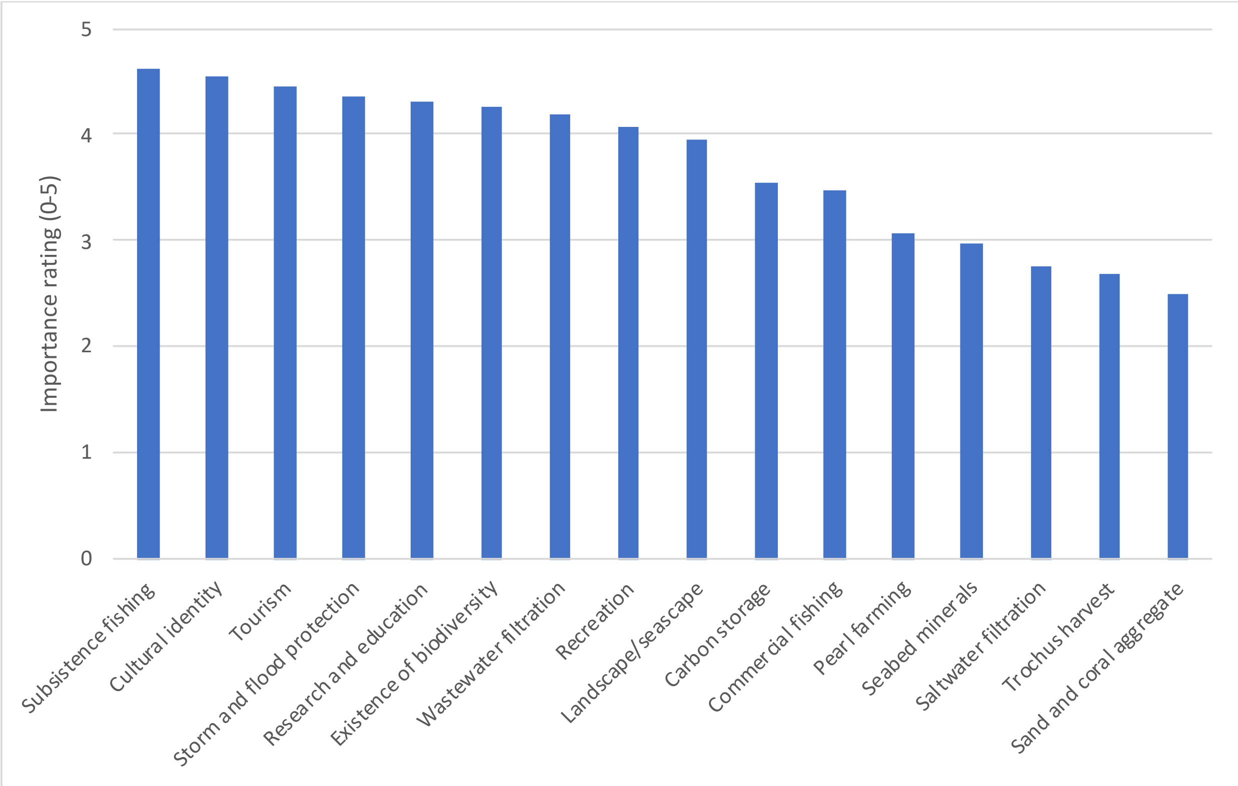

Figure 6. Stakeholder rating of ecosystem service importance

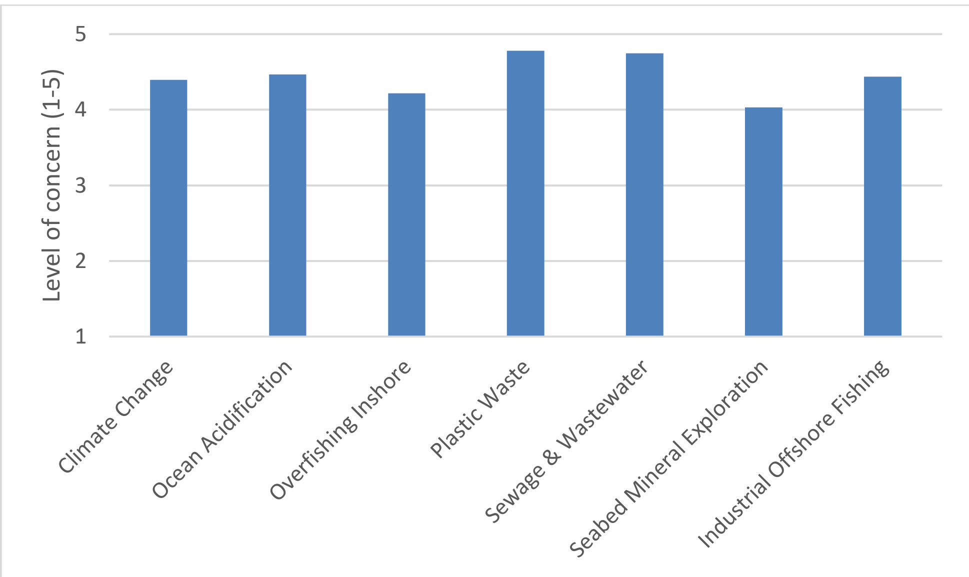

Figure 7. Stakeholder rating of concern for threats to marine environment

6.2 Subsistence fisheries

6.2.1 Identify

Subsistence fishing refers to harvesting of seafood species that are consumed, given, or exchanged by fishers without any monetary transaction. In Pacific Island countries, particularly in rural coastal areas, subsistence fishing contributes significantly to household diets and therefore has substantial *economic value* (Gillett 2009).

By providing appropriate food and habitat conditions, the marine and coastal environment supports the growth and reproduction of a range of fish and invertebrate species that can be harvested for food by humans. Each of the target species requires a particular habitat to grow and reproduce. The reproduction and growth of fished species, and thus the potential magnitude of this ecosystem service, depends on the functions provided by marine habitats, including coral reefs, lagoons and pelagic ocean. The functions of each ecosystem depend on natural geographical and biological factors, such as coastal bathymetry and sea currents, as well as human factors such as pollution, habitat destruction and fishing pressure. Unlike agricultural systems, which require consistent and often intensive human labour, these marine ecosystems can produce food without human intervention as long as they are not damaged or over-exploited.

Many Cook Islands households make use of the marine and coastal environment as a source of food and cash income, i.e. many fishers fish for both subsistence and commercial purposes. The results in this section focus on the value of artisanal fisheries predominantly for subsistence use. Access to coastal resources is linked to land ownership, which is based on traditional land tenure systems whereby families have specific sections of land that are passed on through the family (land cannot be bought or sold, only leased for a short-term period). People access marine resources directly out from their family's sections of land, but not from others if they do not have a tie/claim/stake to that area, or otherwise permission from the landowning family. Even though the legal 'ownership' does not extend to the marine area, this custom still applies. In the outer islands this practice is stronger still, with certain families/ villages only allowed to access the resources in their own areas, even including motus (islets) that are located within 'their part' of the lagoon. Although resources will be combined for large occasions, fishers still remain in their part of the lagoon for collection. Traditional systems of resource management with associated restrictions (ra'ui) are still used. If a ra'ui is placed in an area, there is often a complete ban on any take from that area, or otherwise a complete ban on harvest of a certain species from that area, until the chief declares it to be open again. The strong land tenure laws in the Cook Islands have helped to avoid foreign ownership and ensured extensive access to the marine resources by local residents.

6.2.2 Quantify

The Cook Islands has extensive inshore fish and invertebrate habitat that supports subsistence and artisanal fishing, including reef, lagoon and intertidal shoreline (See Table 1). Inshore fishing habitat covers 665 km^2, which is more than double the total land area of the Cook Islands (236 km^2). The area of coral reef alone covers 229 km^2.

Table 1: Inshore fishing habitat area (km^2) (Source data: Andréfouët et al., 2005)

	Reef	Non-reef	Total
Penrhyn	33.07	188.87	221.94
Rakahanga	4.44	3.79	8.23
Manihiki	14.99	40.31	55.31
Pukapuka	15.85	6.61	22.46
Nassau	1.30	0.00	1.30
Suwarrow	47.53	97.63	145.16
Palmerston	25.18	34.00	59.18
Aitutaki	26.44	61.35	87.79
Manuae and Te Au Otu	15.35	0.00	15.35
Takutea	2.96	0.00	2.96
Atiu	6.33	0.00	6.33
Mitiaro	4.85	0.00	4.85
Mauke	4.54	0.00	4.54
Rarotonga	17.50	3.75	21.25
Mangaia	8.34	0.00	8.34
Cook Islands	228.66	436.31	664.96

The MESV household survey collected information on the type, frequency and quantities of fish and shellfish harvested from the marine and coastal environment. The proportions of households engaging in subsistence harvesting of ocean fish, reef fish and shellfish are 27%, 30% and 28% respectively. Using information on the frequency of fishing trips and the average weight of catch, we estimate the average quantity of harvest per household (see Figure 8). The total annual harvest is estimated by multiplying the average household harvest by the number of households (4,435 – CISO 2018) – see Table 2.

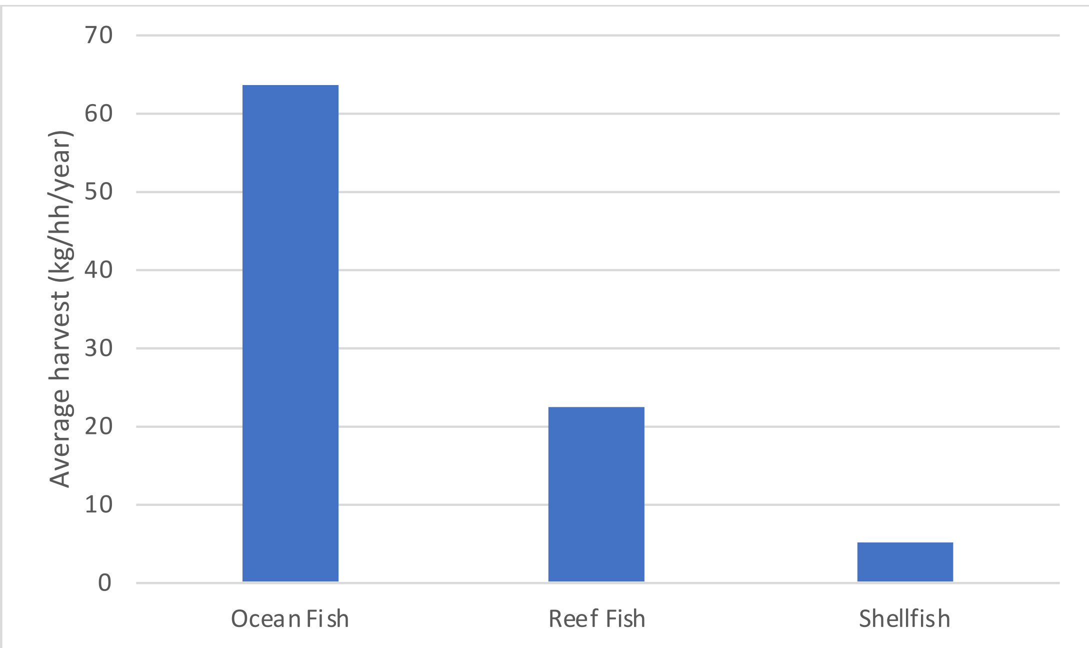

Figure 8. Average household subsistence harvest of fish and shellfish (kg/household/year)

6.2.3 Value

The value of the subsistence fishery ecosystem service can be estimated from fish and invertebrate harvest data, multiplied by relevant local prices[6], less the costs of subsistence fishing techniques[7], as illustrated by the equation:

$$Value\ (Benefit) = \left(Subsistence\ Harvest_{kg} * Price\ Food\ Equiv._{\frac{\$}{kg}}\right) - Harvest\ Costs_{\$}$$

This formula is applied to estimate the value of subsistence fisheries in Table 2. The gross value of subsistence fishing is estimated by multiplying the total annual harvest by average market prices, which were obtained from MMR and Gillett (2016).

The costs of subsistence fishing include basic fishing gear, such as lines, hooks, nets, spears, goggles and lights, as well as boats and boat-related expenses such as fuel and maintenance. These annualised capital and variable costs must be subtracted from the gross value of harvest to determine the net *economic value* of subsistence fishing. Subsistence fishers are not paid a wage, but their time has value. It can be the case that when an *opportunity cost* of labour (such as the average local wage rate) is subtracted from the value of the fish caught, the value of subsistence fishing is negative. In other words, fishers are earning less per hour than the typical wage rate. Subtracting the *opportunity costs* of wage labour may be applicable in some cases where wage-earning jobs are available to fishers, but in many instances, particularly in remote villages where there are no other employment opportunities, there are no true *opportunity costs* for subsistence fishers. We therefore do not subtract an estimate of the opportunity cost of time in estimating the net value of subsistence fishing.

Information on the costs of subsistence fishing is not available so we use estimates based on data for fuel costs from MMR for a lower bound cost (16% of gross revenue) and from the commercial fishing sector as an upper bound cost (53% of gross revenue). This range of costs is used to estimate the range of net values for subsistence fishing (NZD 2.6 – 4.7 million per year). For example, the lower bound estimate of net value (NZD 2,627,108) is computed as the gross value (NZD 5,589,591) minus the higher bound estimate of costs (NZD 2,962,483). The mid-point in the estimated range of net value is NZD 3,661,182.[8]

Comparing these results with earlier estimates of artisanal and subsistence fisheries in the Cook Islands provide some measure of context and validation. The HIES (2016) reports that annual national household income from fisheries is NZD 544,990. This is a measure of cash income from the sale of harvested fish and does not include subsistence use. Subtracting this from our estimates implies that subsistence use accounts for 79-88% of household harvest.

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[6] The relevant prices are for commodities that would be substituted in the absence of the harvested resource. This might be the same type of fresh fish available at local markets or other forms of protein (e.g., canned meat). Alternatively, resource harvesters might choose to sell their catch instead of consuming it themselves, in which case the relevant price would be the price they can sell it for.

[7] Ideally, value would be calculated separately for each different fishing technique (gleaning, spearing, nets, handline) since the harvests and costs vary accordingly.

[8] All calculations and data are available in a supplementary Excel file.

Gillett (2016) estimates that subsistence fisheries in 2014 amounted to 276,000 kg with a net value of NZD 2 million, which is a little lower but similar magnitude to the estimates produced in this report.

Table 2: Value of subsistence fisheries

	Ocean fish	Reef fish	Shellfish	Total
Average household harvest (kg/household/year)	64	22	5	91
Total harvest (kg/year)	282,873	99,457	23,442	405,772
Average price (NZD/kg)	12	15	30	
Gross value (NZD/year)	3,394,473	1,491,856	703,262	5,589,591
Average household value (NZD/household/year)	765	336	159	1,260
Cost – low (% of revenue)	543,116	238,697	112,522	894,335
Cost – high (% of revenue)	1,799,071	790,684	372,729	2,962,483
Net value – low (NZD/year)	1,595,402	701,173	330,533	2,627,108
Net value – high (NZD/year)	2,851,357	1,253,159	590,740	4,695,257

6.2.4 Uncertainty

There is little reliable data for subsistence fisheries in the Pacific. Most estimates are dubious extrapolations from isolated and/or old data sets that have chronically underestimated subsistence harvests (Zeller et al., 2014).

The estimates in this report are based on the MESV household survey, which has a small sample that is likely to under-represent households that rely heavily on subsistence fishing. As such, the estimated quantities and values may be an underestimate of the actual scale of subsistence fishing.

6.2.5 Sustainability

The Cook Islands' extensive fish and invertebrate habitats should be sufficiently productive to maintain a sustainable source of seafood for households that depend on subsistence activities. However, resource pressure can be highly localised around villages and care should be taken to avoid localised over-harvesting. Raui's are traditionally used to allow an area to regenerate. After a given amount of time, the closed area reopens and the ra'ui rotates to another area so that can regenerate. This traditional system of conservation historically works well. It is, however, becoming less effective and is poorly regulated and enforced in many islands, most of all Rarotonga, hence areas are not able to replenish and are at high risk of depletion.

6.2.6 Distribution

The benefits from subsistence fishing accrue entirely to households within the Cook Islands. Subsistence fishing does not generate government *revenue* or foreign exchange, which means that it can be easily neglected in economic planning and policy-making. Despite the uncertainty in subsistence fishing data, the proximity of households to marine resources and the limited relative income available to most Cook Islands households to purchase imported and/or processed foods indicate that subsistence fishing is, and will continue to be, essential for food security and the wellbeing of Cook Islands families. This is particularly true for families further away from main economic centres and close to nearshore lagoon and reef habitats that are accessible to fishing with minimal costs.

6.3 Commercial fisheries

This section evaluates the harvest of seafood that is sold or exchanged via a monetary transaction. Commercial fishing is a large component of many Pacific Island economies. The EEZs of Pacific Island countries are home to large fish stocks that are used to provide food for people throughout the world. The Western Pacific skipjack tuna fishery is one of the world's largest natural sources of animal protein and white meat albacore tuna from southern Pacific waters is canned and sold world-wide. Millions of square kilometres of reef and lagoon habitat support the reproduction of a wide variety of commercially popular seafood.

Commercial fishing is divided into inshore fisheries and offshore fisheries. Inshore fisheries occur in any reef, lagoon, intertidal zones or other areas that have relatively shallow water and are home to non-migratory fish and invertebrate species. Offshore fisheries occur in deep-water areas that are home to commercially viable species such as sharks, billfish, and tuna. In this section, the focus is on offshore commercial fisheries.

6.3.1 Identify

Like most Pacific Island countries, offshore fishing in the Cook Islands is mostly for commercial sale and export. Although deep-water and pelagic fish species are sometimes caught by artisanal fishers near to shore, offshore fishing is generally characterised by more expensive and sophisticated equipment than is used for inshore fishing.

Currently there is only one Cook Islands-owned and operated offshore fishing company, Ocean Fresh, which operates two Rarotonga-based longline vessels. The majority of offshore fishing is undertaken by foreign-based vessels, which comprise of two types: 1. Longliners, of which there were 33 vessels operating in the Cook Islands zone in 2018 (MMR, 2019); 2. Purse seiners, of which there were 50 authorised to fish in Cook Island waters in 2018 (MMR, 2019).

6.3.2 Quantify

The level of fishing effort and catch for the domestically-owned and operated longline vessels in 2019 are reported in Table 3. The volume of catch by foreign-based longline and purse seine vessels 2018 is reported in Table 4.

Table 3: Fishing effort and catch (metric tonnes – mt) for domestically owned longline vessels in 2019

Days	520
Fishing effort (hooks set per year)	1,299,600
Catch per unit effort – CPUE (kg/1000 hooks)	143
Total catch (mt/year)	186

Table 4: Fishing effort and catch (metric tonnes – mt) for foreign-based longline and purse seine vessels in 2018 (source: MMR 2019)

Longline vessels	33
Longline catch (mt/year)	4,050
Albacore (mt/year)	3,075
Yellowfin (mt/year)	531
Bigeye (mt/year)	195
Blue marlin (mt/year)	108
Swordfish (mt/year)	41
Purse seine vessels	50
Purse seine catch (mt/year)	34,400

6.3.3 Value

The net *economic benefit* (to fishers) of this ecosystem service can be estimated by subtracting fishing costs from the *gross value* of the catch. The remaining value is the *value-added* of the sector.

The revenue, costs and net value for the domestically-owned longline operator in 2019 are reported in Table 5. Information on costs is not available for the foreign-owned operators, so we assume that they have the same value-added ratio as the domestic operators. It is possible, however, that the foreign owned vessels face lower costs, and so this assumption would result in an underestimate of the actual net value of the fishery. This underestimate in costs is likely to be even greater for the purse seine fishery where costs per unit are likely to be much lower. The revenues and net value for foreign based longline and purse seine vessels in 2018 are reported in Table 6. In Table 5 and 6, the estimated net value is computed as the gross revenue minus the cost. For example, for domestically owned longline vessels NZD 1,855,370 - NZD 1,000,000 = NZD 855,370.

Table 5: Revenue, costs and net value for domestically-owned longline vessels in 2019

Total catch (mt/year)	185
Average value of fish (NZD/kg)	10
Gross value of catch (NZD/year)	1,855,370
Costs - licence, fuel, crew, bait, maintenance (NZD/year)	1,000,000
Cost proportion of revenue	54%
Net value (NZD/year)	855,370

Table 6: Revenue, costs and net value for foreign-based longline and purse seine vessels in 2018

Longline gross value of catch (NZD/year)	40,500,000
Longline cost (NZD/year)	21,828,530
Longline net value (NZD/year)	18,671,470
Purse seine gross value of catch (NZD/year)	68,800,000
Purse seine cost (NZD/year)	37,081,552
Purse seine net value (NZD/year)	31,718,448
Total net value (NZD/year)	50,389,917

6.3.4 Uncertainty

There is much uncertainty about appropriate fishing costs or *value-added* ratios for foreign-based vessels. Fishing *value-added*/ cost ratios reported in the literature range from 80% to 20%. The 54% cost ratio used above is a conservative estimate, which may underestimate the true *economic value* of the fishery if foreign owned vessels, and particularly the purse seine vessels, face lower operating costs.

6.3.5 Sustainability

Stock assessments from 2010 show that South Pacific albacore stocks remain sustainable despite evidence of perennial increases in fishing effort and decreases in CPUE that have been forcing a significant contraction of commercial longline fishing (SPC, 2014b). The longline technique of fishing tends to harvest older fish that have already had a chance to reproduce, making longline fisheries less susceptible to overfishing than purse seine fisheries. However, fleets report significant declines in harvest and decline in CPUE. Bycatch from commercial fishing is likely to impact the populations of some non-target species (Hall et al., 2017).

6.3.6 Distribution

The offshore commercial fishery is clearly dominated by foreign-based vessels. In 2018, the 50 authorised purse seine fishing vessels comprised 16 Korean-, 6 Kiribatian-, 2 Vanuatuan-, 2 Nauruan-, 2 Spanish-, 1 Marshallese-, and 1 Tuvaluan-flagged vessel, in addition to the US multilateral Treaty vessels (MMR, 2019). It is important to note that the majority of the estimated value of commercial fisheries accrues to foreign owned vessels. The Cook Islands only benefits from their licence fees and sale of catch quotas, which was approximately NZD 18 million in 2019 (MFEM 2020c), and incurs the cost of managing the resource.

6.4 Trochus

6.4.1 Identify

Trochus is a type of medium- to large-sized marine gastropod mollusc (sea snail). *Tectus niloticus* (trochus) was introduced to the Cook Islands, and specifically to Aitutaki, in 1957. This sea snail is harvested primarily for its shell, which is used to make mother of pearl buttons and decorative ornaments. Trochus are usually collected while snorkelling or wading on the back reef shelf. The first commercial harvest of trochus took place in 1981. This harvest was comparatively unregulated, and around 200 tonnes of trochus were reported to have been harvested over a 15-month period (MMR 2012).

At Aitutaki, trochus are normally harvested after resource surveys have been completed and have determined an average density of greater than 500 trochus per hectare. Thirteen organised community harvests have occurred prior to 2012 (MMR 2012).

The Aitutaki trochus fishery is managed by the Island Council following the principles of: sustainability, ease of implementing a harvest, enforcement of management measures and fair distribution of the benefits to the community. The management approaches developed includes size limits with a minimum of 80mm and a maximum of 110mm basal diameter, short harvest season, and an overall harvest quota that is subdivided equally among the resident community (MMR 2012).

6.4.2 Quantify

Trochus harvests do not take place every year, and the most recent harvest was in 2015 on Aitutaki. Data on the location, year and harvested weight of trochus is reported in Table 7.

Table 7: Trochus harvest and value 1981-2015 (source: MMR and Raymond Newnham)

Location	Year	Harvest (mt)	Price (NZD/mt)	Gross Value (NZD)
Aitutaki	1981	200	850	170,000
Aitutaki	1983	35.7	1,250	44,625
Aitutaki	1984	45.7	1,450	66,265
Aitutaki	1985	27	1,800	48,600
Aitutaki	1987	45.1	2,000	90,200
Aitutaki	1988	18	3,000	54,000
Aitutaki	1990	26.2	7,000	183,400
Aitutaki	1992	28	6,350	177,800
Aitutaki	1995	34	6,000	204,000
Palmerston	1997	1.5		
Aitutaki	1997	18.4	6,250	115,000
Aitutaki	1998	31.4	6,500	204,100
Aitutaki	1999	18	8,250	148,500
Aitutaki	2001	37	8,500	314,500
Rarotonga	2001	24.5	1,255	30,748
Manihiki	2005	3.9		
Aitutaki	2011	18.9	832	15,725
Aitutaki	2015	19.8	4,126	81,700
35-year total		633		1,949,162
Annualised		18		55,690

6.4.3 Value

The gross value of harvested trochus shells is estimated by multiplying the harvested weight of shells by the price (see Table 7). The trochus meat might also have some value, but very little is sold, and most is eaten by the harvesting families (Newnham – pers. com.). The estimation of the net value to harvesters requires information on the costs of harvesting, which is not available. The costs of harvesting are assumed to be low and mainly comprise fuel for boats. Harvesting and cleaning does, however, require a large amount of time (Tiraa-Passfield et al, 2011).

To arrive at an annual value of trochus harvest, we calculate an annualised value over the 35-year period that harvesting has taken place. This gives an annual value of almost NZD 56,000.

6.4.4 Uncertainty

The value of trochus harvesting is uncertain and highly variable due to fluctuation in the price of the shells. Currently there is an over-supply in the Pacific and the price is low. In addition, it is not a resource that can be harvested on a regular annual basis, and depends on the assessed density across locations.

6.4.5 Sustainability

The trochus resource is systematically monitored, and each harvest is well regulated. Moreover, assigned harvest quotas are not necessarily filled.

6.4.6 Distribution

The value of trochus is primarily a benefit to local families that participate in the harvest. There appears to be interest in improving the post-harvest processing and adding value to the products.

6.5 Pearls

6.5.1 Identify

Pearl farming is currently the most significant type of aquaculture in the Cook Islands (Gillett 2016). Production has declined since its peak in 2000 when there were 81 farms producing an annual yield worth approximately NZD 18 million. At this time, pearls accounted for a large share of exports and approximately 20% of GDP (MMR, 2012; Gillett, 2016). Production has declined during the past 20 years due to bacterial infection and declining prices in the global pearl market (Hambrey, 2011; Gillett, 2016), and in 2014 there were about 10 active pearl farms, with a further 14 farms operating at a minimal level (Brown, 2015).

6.5.2 Quantify

The quantity of pearls bought by the Cook Island pearl exchange is reported in Table 8. This does not, however, represent the total production of pearls, which are also sold directly to local retailers or exported. Data on the exports of pearls and pearl shells are available but reported by value only, not by weight or number. A rough estimate of the total number of pearls produced in 2019 is 30,000 pieces (Raymond Newnham, pers. com.).

6.5.3 Value

The value of pearls bought by the Cook Island pearl exchange is provided in Table 8. The net value is calculated using a rough estimate of the cost of production at NZD 10 per piece (Raymond Newnham, pers. com.). The value of pearl exports is reported in Table 9.

To arrive at an estimate of the total net value of pearl production in 2019 we multiply the estimated total production (30,000 pieces) by a price of NZD 20/piece (under the assumption that the price of directly sold and exported pearls are likely to be higher than at the pearl exchange) less the estimated production cost of NZD 10/piece. This gives an estimated total net value of pearl production of NZD 300,000.[9]

Table 8: Quantity of pearls bought by the Cook Island pearl exchange 2015-2019 (Source: Inshore & Aquaculture Fisheries Division, MMR)

Year	Pearls (pieces)	Price (NZD/piece)	Gross value (NZD)	Net value (NZD)
2016	5,130	12.87	66,023	14,723
2017	6,477	14.64	94,823	30,053
2018	2,635	13.04	34,360	8,010
2019	10,458	17.45	182,492	77,912

[9] 30,000*(20-10) = 300,000

Table 9: Value of pearl exports 2011-2019 (Source: MMR)

Financial Year	Pearls (NZD)	Pearl Shells (NZD)	Total (NZD)
2011/12	339,000	211,000	550,000
2012/13	241,294	50,000	291,294
2013/14	203,000	49,000	252,000
2014/15	301,000	118,000	419,000
2015/16	314,000	49,000	363,000
2016/17	203,364	42,000	245,364
2017/18	219,000	-	219,000
2018/19	106,971	720	107,691
2019/20	42,894	86,000	128,894

6.5.4 Uncertainty

The estimated value of pearl production is based on approximate numbers for the total production, price per pearl and also the cost of production. This value is therefore highly uncertain.

6.5.5 Sustainability

The production of pearls is a closely managed aquaculture process that is not prone to overharvesting or other challenges facing open access renewable resources. It is, however, susceptible to external impacts in terms of disease, climate change and price fluctuations. Globally the production of pearls has become more concentrated and the scale of production has increased, leading to lower prices (Tisdell and Poirine, 2008; Johnston et al, 2019).

6.5.6 Distribution

In the Cook Islands, pearl aquaculture is conducted by small producers and the benefits accrue to these local businesses and employees. Pearl aquaculture is particularly concentrated in the Northern Group, predominantly Manihiki, although family members/businesses based in Rarotonga that on sell them also benefit.

6.6 Sand and coral aggregate

6.6.1 Identify

Sand and aggregate are required in the production of construction materials such as concrete and asphalt. These materials are either quarried from rock, or mined from land or sea. In Pacific Island countries, which have limited land and rock resources, sand and aggregate is often mined from beaches, lagoons and reefs and is mostly composed of dead coral. In some places, entire structures and sea walls are constructed from coral that has been broken into stackable bricks. Sand and coral may also be used for beautification of gardens. Clearly this material provides an important service to island communities. Unfortunately, coral does not grow fast enough to be considered a renewable resource.

Since sand and coral aggregate are important construction materials, these resources have substantial value to businesses and consumers. Mining, however, can also have significant negative externalities, un-priced costs or harms that accrue outside of the mining industry. For example, if sand mining on a beach induces saltwater intrusion that contaminates the groundwater supply to local villages; the loss of clean groundwater is a negative externality of beach mining. Coastal erosion and siltation of reefs are other potential externalities of coral aggregate mining, which suggests that mining might negatively affect the provision of other ecosystem services such as coastal protection or fishing.

6.6.2 Quantify

Only limited information could be obtained on the quantities of sand and coral aggregate extracted from the marine environment. This information is summarised in Table 10. To make a rough extrapolation from this data, we estimate the annual average quantities of sand (0.7 m^3) and coral aggregate (0.4 m^3) per person. Multiplying these averages by the population of each island (excluding Rarotonga, on which sand and aggregate are obtained from terrestrial sources) gives a rough estimate of the total quantities extracted each year: 3,068 m^3 sand and 1,871 m^3 coral aggregate.

Table 10: Quantities of extracted sand and coral aggregate

Resource	Source Ecosystem	Island	Quantity (m3)	Year	Use
Sand	Coastal	Manihiki	200	2019	Building construction
Sand	Foreshore	Manihiki	300	2020	Building construction
Sand	Beach	Palmerston	16	2019	Beautification of gardens
Sand	Beach	Palmerston	8	2020	Beautification of gardens
Sand and Coral	Coastal	Mangaia	144	2020	Building construction, road repairs, earth works
Coral aggregate	Foreshore	Manihiki	150	2020	Building construction
Coral aggregate	-	Palmerston	8	2019	Construction

6.6.3 Value

Information on the value of sand and coral aggregate is also very limited, particularly as in general no charge is levied for the extraction of these resources. Users generally only pay for the transportation but not for the material itself. In one case the approximate cost of one load of 3 m^3 of mixed sand and coral aggregate was NZD 100 (i.e. NZD 33.33 per 1 m^3). Multiplying this price by the estimated total annual quantities of extracted sand and coral aggregate gives an annual value of NZD 102,274 and NZD 62,382 respectively.

6.6.4 Uncertainty

The estimated quantities and values of sand and coral aggregate are extrapolations from a very limited set of observations. As such they are highly uncertain, and a more complete survey of the use of these resources would be required to produce more accurate numbers.

6.6.5 Sustainability

Beach and coral mining destroy habitat for fish, invertebrates, crabs, turtles and other species. It can also leave coastal areas more vulnerable to erosion and sea-surge inundation and lead to saltwater intrusion into the groundwater.

6.6.6 Distribution

The use of sand and coral aggregate for construction and other purposes directly benefits Cook Island households and businesses.

6.7 Seabed minerals

6.7.1 Identify

Manganese nodules are rock-like minerals that contain manganese and limited amounts of nickel, copper, titanium, cobalt, and rare earth elements. They range in size from as small as a golf ball to as large as a potato, and are found lying loosely on the sediment covered abyssal plains of the world's deep-sea basins at depths ranging from 3,500 to 6,000 metres (SPC, 2016; McCormack, 2016).

6.7.2 Quantify

The Penrhyn basin in the Cook Islands is one of four primary locations in the world with sufficiently high densities of manganese nodules for extraction to potentially be commercially viable. The Penrhyn Basin is known to have a high concentration of nodules over a very large area (Hein et al., 2015). A recent study reports very high nodule abundance (>25 kg/m2) covering approximately 124,000 km^2 and contains 3.6 billion tonnes in wet nodules (Hein et al., 2015). The abundance of nodules within the Cook Islands EEZ is represented in Figure 9. Further information on seabed mineral resources can be obtained from the Cook Islands Seabed Minerals Authority (https://www.sbma.gov.ck/) and McCormack (2016).

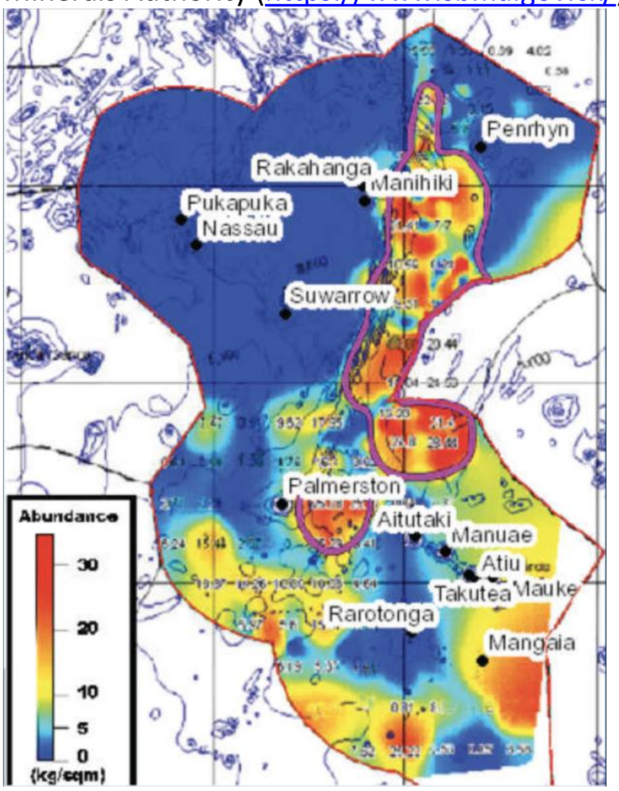

Figure 9. Abundance of manganese nodules in the Cook Islands EEZ (source: SPC, 2016)

SPC (2016) reports the results of a cost-benefit analysis of seabed mineral extraction. The mining scenario assumes that 135 km^2 of seafloor will be mined annually implying a 20-year mining operation that yields 2.5 million dry tonnes of nodules per year, for a total of 50 million tonnes over the course of the operation.

6.7.3 Value

McCormack (2016) provides an estimate of the potential future gross value of seabed mineral extraction from a single 135 km^2 mine. The annual gross value of the minerals from 2.5 million dry tonnes of nodules per year is approximately NZD 2 billion per year. Assuming a simple 3% resource royalty to the Government of the Cook Islands, the annual royalty revenue would be approximately NZD 65 million per year. It is possible that the Central Area of the South Penrhyn Basin could support two such mines, which would increase the royalty revenue. The scale of such production, however, would be likely to have a downward effect on global mineral prices and result in lower gross value and associated royalties.

The net benefit of deep-sea mining depends on the market prices of minerals extracted, the extraction costs, and the costs of external impacts. It is not possible to assess these values within the scope of this report.

The external costs of seabed mining are any negative changes in welfare incurred by citizens or businesses of the host country or elsewhere, potentially through environmental impacts and loss of ecosystem services (SPC, 2016; Le et al., 2017). Potential environmental impacts with associated external costs are summarised in Table 11.

Table 11: Potential environmental impacts of seabed mineral extraction (SPC, 2016)

Environmental impact	Description
Changes in the provision of ecosystem services	Mining activities can disrupt services provided by marine ecosystems, including fisheries and tourism
Greenhouse gas emissions from operations	Emissions of carbon dioxide (CO_2) and other greenhouse gases by mining and processing activities
Release of carbon stored in marine sediment	Mining activities that disturb marine sediment could cause the release of stored carbon
Pollution of surface water	Discharge of nutrient rich water or pollutants can affect surface water quality and marine life
Unplanned oil releases	Unplanned releases of oil into the marine environment during mining or transport operations can impact marine life
Noise pollution and degradation of viewscapes	Operation of on-island processing facilities can result in visual degradation, noise, waste, and unplanned release risks

The deep-sea environment where nodule mining takes place is characterized by extreme conditions. Organisms belonging to this habitat are likely to be negatively impacted by disruption to their environment and some could face local extinction (Levin et al., 2020). Several studies examine the potential impacts of seabed mining on deep sea habitats and highlight that the main threats are from low frequency noise propagation and drifting sediment plumes. These alterations can affect species distributions or ecosystem functioning (Miller et al., 2018; Weaver et al., 2018). There is also the risk that the operations may result in the unintentional introduction of hazardous materials into the marine environment.

Several economic reports have assessed the external costs and benefits of mining deep-sea minerals in different mining scenarios in the Pacific Island Region, including the Cook Islands (SPC, 2016; Wakefield et al., 2018). The unplanned release of oil could potentially result in three types of costs: clean-up costs, production loss, and loss of ecosystem services (Wakefield et al., 2018). The potential loss of ecosystem services from deep seabed communities in Cook Islands has been estimated at USD 24.9 million (SPC, 2016). In addition, the potential cost of clean-up and compensation for unplanned spills and grounding is estimated as USD 0.2 million (SPC, 2016).

A political framework is needed to protect these ecosystems from deep sea minerals mining and avoid the possible impact on biodiversity loss (Van Dover et al., 2018). To this end, the Draft Environment (Seabed Minerals Activities) Regulations 2020 under the Environment Act 2003 have been circulated for comments and are expected to be passed by Cabinet this year.

The possibility of high and irreversible external costs needs to be carefully considered by incorporating ecosystem services into international deep-sea mining regulation (Le et al., 2017). At a minimum, it is necessary to carry out an environmental impact assessment before exploitation licenses are issued (Bourrel et al., 2018; Bradlet et al., 2018; Durden et al., 2018; Levin et al., 2016).

6.7.4 Uncertainty

The benefits of seabed mineral mining for the Cook Islands remain unknown. Very few deep-sea mining operations exist, and the costs and benefits remain largely speculative. In light of this high uncertainty, countries are advised to proceed with caution and avoid taking on significant financial risk investing in deep-sea mining enterprises. From an ecosystem services perspective, there are risks in jeopardising other services, particularly deep-sea and pelagic fisheries.

6.7.5 Sustainability

Mining is necessary to obtain minerals that are inputs in the production of goods that people consume. Mining involves the extraction of non-renewable resources and is therefore not a sustainable activity in itself. Whether mining is ecologically sustainable in terms of long-term degradation of the environment in which it takes place depends on the type of mining activity and the sensitivity of the environment. If negative externalities can be avoided or minimised, deep-sea mining may be economically sustainable and efficient, particularly if it can be shown to be less environmentally damaging than land-based mining. Of greatest concern for the Cook Island should be the potential impacts on commercial fishing, tourism and biodiveristy.

6.7.6 Distribution

Since the mining operations are likely to be 100% foreign-owned, most of the producer surplus (*profit*) will go to foreign companies and the consumers who benefit from lower cost metals and minerals. In the near term, most local benefits are likely to accrue to government in the form of licence fees, taxes, and royalties. These benefits may be redistributed to civil society by way of improved social programs, infrastructure or other public services. There are some potential employment opportunities for Cook Islanders, but most employment will be for highly specialised, overseas-trained ocean miners.

6.8 Coastal protection

Tropical cyclones are a common seasonal occurrence in the South Pacific and the Cooks Islands is vulnerable to storm damage due to coastal flooding, high winds and torrential rain (de Scally, 2006; 2014; Blacka et al., 2013). For example, in 1987, tropical cyclone Sally directly hit Rarotonga causing damage equivalent to 66% of the Cook Islands GDP (Bettencourt et al., 2006; de Scally, 2014). On average, 11 tropical cyclones pass within 400 km of Rarotonga per decade, i.e., just over one per year (Blacka et al., 2013).

6.8.1 Identify

The ecosystem service of coastal protection includes different roles that ecosystems can play in protecting coastal areas. The two main roles identified and described here are:

(i) Prevention of erosion, sediment provision and/or accretion
(ii) Mitigation of storm surges

These two different forms of coastal protection differ in their impacts. The first provides long-term protection against the wearing away of land and removal and deposition of sediments (erosion, accretion). The second offers short-term protection against coastal floods and storm surges. The short-term protection happens episodically, and the damage avoided is clearly identifiable (damaged buildings, roads, crops), while the effects of long-term protection are more diffuse over time.

6.8.1.1 Erosion prevention and sediment provision

Coastal ecosystems in the Cook Islands play an important role in stabilisation of shorelines. The increase of human density along coasts and the resultant increasing pressures on coastal ecosystems leads to a paradox: an increased need to stabilise shorelines, but a decline in natural stabilising processes.

Coral reefs are known to contribute to beach formation, even though the processes involved are not yet well described (Pérez-Maqueo et al., 2007). Beach formation occurs with accumulation of sediments from various origins (marine or alluvial), a phenomenon known as sedimentation. Coastlines near coral reefs receive sediments from this ecosystem in the form of small dead coral particles. Accumulation on the coastline of those sediments is the source of beach formation. Sedimentary accretion also maintains and nourishes beaches, in opposition to natural or anthropogenic erosion (Huang et al., 2007).

The scope of this study was to identify all ecosystem services at a national scale and, where possible, quantify and value those with readily available data. Many authors agree that assessment of erosion prevention and sediment provision is a data-demanding exercise and requires a fine resolution of analysis (Lugo-Fernandez et al., 1998; Penning-Rowsell et al., 2003; Van Der Meulen et al., 2004). For example, on a 1km scale, neighbouring beaches can suffer both erosion and sand accretion depending on geomorphological and biological factors (Brander et al., 2004). Although it has not been possible to precisely quantify the ecosystem service of protection against erosion, three major aspects have been identified for the Cook Islands:

(i) stabilisation of shorelines, critical in high human density sites
(ii) beach formation and stabilisation, important in tourist areas
(iii) atoll formation and stabilisation, very important for atoll islands.

In the Cook Islands, reefs may play a major role in the formation and stabilisation of beaches, which are important assets for local tourism.

The role of coral reefs in erosion protection (sedimentation and accretion) is not well understood and it is difficult to quantify and estimate the *economic value* of such processes with any precision.

6.8.1.2 Storm surge mitigation

Storm surge mitigation by coral reefs is one of the most important aspects of coastal protection provided by marine ecosystems (Laurans et al., 2013). As a point of reference, average annual direct loss caused by flooding associated with tropical cyclones in 15 South Pacific countries was calculated to be up to US$ 80 million (2009 prices), with 60% of the damage resulting from loss of residential buildings, 30% from loss of cash crops and 10% from damage to infrastructure (PCRAFI, 2011).

Storm systems such as tropical cyclones and mid-latitude storms and their associated cold fronts are the primary causes of storm surges[10]. Storm surges can interact with other ocean processes such as tides and waves to further increase coastal sea levels and flooding and have maximum impact when they coincide with high tide. Breaking waves at the coast can also produce an increase in coastal sea levels, known as wave setup. Storm surges occurring at higher mean sea levels enable damaging waves to penetrate further inland, which increases flooding, erosion and damage to built infrastructure and natural ecosystems. The effect of rising mean sea levels due to climate change will be felt most profoundly during tsunamis or extreme storm conditions (CSIRO and Australian Bureau of Meteorology, 2007)[11].

Coastal bathymetry (shape and depth of sea or ocean floor) and the presence of bays and headlands and the proximity of other islands also affect the height of storm surges. Wide and gently sloping continental shelves amplify storm surges, while bays and channels can funnel and increase the height of storm surges.

Coral reefs provide protection against waves by forming barriers along the coastline. As a result, lagoons, which are protected by barrier reefs, are relatively calm areas that provide multiple ecosystem services (e.g. biomass production, scenic beauty). Several studies have shown that reefs act in a similar manner to breakwaters or shallow coasts (Lugo-Fernandez et al. 1998; Brander et al. 2004; Kench and Brander 2009). They impose strong constraints on the swell of the ocean, resulting in transformations of wave characteristics and a rapid attenuation of wave energy.

Waves formed by the wind store a large part of their energy at the surface, and this force can be absorbed by fringing reefs and reef crests, sometimes up to 90% at low tide (Lugo-Fernandez et al., 1998). The degree of energy absorption is highly variable and depends on the type of reef, the depth and the waves (Kench and Brander, 2009). The role of coral reefs in coastal protection is difficult to isolate from other variables and, in fact, a combination of factors affect the level of protection provided. The primary factors influencing attenuation of wave energy are (Burke 2004):

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[10] A storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

[11] A tsunami differs from a wind-generated wave in that the former is much larger and its energy is distributed throughout the water column. The impact of bathymetry in wave attenuation is even more important in tsunamis due to this vertically continuous distribution of energy throughout the column water rather than the surface distribution of storm surge waves.

1. Bathymetry (shape and depth of sea or ocean floor)
2. Geomorphology (soil origin and composition)
3. Topography (coastal and inland surface shape, as well as shoreline indentations) and,
4. Biological cover (presence of other ecosystems in the coastal area, i.e, coral reefs).

Few studies have focused on isolating the specific role of coral reefs within this combination of factors (Badola and Hussain 2005). In addition to the complexity of quantifying the specific contribution of coral reefs to coastal protection, an analysis by Barbier et al. (2008) found that the relationship between reef area and absorption of wave emerge was nonlinear.

6.8.2 Quantify

Two methods can be used to assess the role of coral reefs in coastal protection: methods based on biological properties of reefs, and methods based on physical and mechanical properties of the reefs. Due to the large quantity of information required for the biological method, and the requirement of small study areas, the physical and mechanical approach is generally more tractable. One of the main limitations of this approach is that it is not able to assess the complete relationship between coral mortality and its role in loss of the coastal protection service.

The approach used for deriving a coastal protection index in this study is through an analysis of the spatial configuration of coral reefs, coral cover, land elevation, vegetation and population centres. These physical characteristics were used to give a descriptive assessment of vulnerability to storm damage, which is then given a score between 0 and 1 as an index value for each group of islands or atoll – see Table 12. The maps used in the assessment are provided in Appendix V.

Table 12: Calculation of the coastal protection index based on characteristics of the coastline

	Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Coastal protection index (0-1)	Assets at Risk
Penrhyn	91	2x inhabited islands: Pokerekere & Moananui	Both villages Omaka (on Moananui isl.) and Te Tautua (on Pokerekere isl.) are located on the inner/lagoon side of the islands. Given the steep drop at the edge of the reef flats, forereef and lack of reef area may result in coastal flooding and damage to infrastructure during severe storm surges. In addition, both villages may take severe damage if severe storm surges were to occur from the inner lagoon	0.4	Potential infrastructure damage includes: roads, buildings and jetties
Rakahanga	9	1 x inhabited island, Rakahanga	Nivano Village is sheltered by both reef flats & forereef. It is also protected by vegetation as well as an island (Te Kainga) just off the village.	0.9	Unlikely due to geographical location, surrounding vegetation and reefs.
Manihiki	93	2x Tauhunu isl. & Ngake isl.	Both villages Tauhunu (on Tauhunu isl.) and Tukao (on Ngake isl.) are located on the inner/lagoon side of the islands. Given the steep drop at the edge of the reef flats, forereef and lack of reef area may result in coastal flooding and damage to infrastructure during severe storm surges. In addition, both villages may take severe damage if severe storm surges were to occur from the inner lagoon	0.4	Potential infrastructure damage includes: roads, buildings and jetties
Pukapuka	12	3x Pukapuka, Motu Kotawa & Motu koe	All 3 villages are well sheltered in terms of geographical location, vegetation cover & surrounding reef area. Coastal damage may occur only during severe weather conditions.	0.8	Infrastructure damage may occur only during severe weather conditions. Potential infrastructure damage includes: roads, buildings and jetties

	Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Coastal protection index (0-1)	Assets at Risk
Nassau	1	1 x Nassau isl.	Kikau village has an approximate distance of 150m from its beach to reef edge. Kikau village buildings are about 90-100m inland (from the beach). It is well sheltered by uplifted reef flats and reef edge.	0.9	Damage would mainly be caused by falling debris from surrounding vegetation (during strong winds or storm surges).
Suwarrow	42	0	Given its remote location and uninhabited islands Suwarrows main vulnerability would be the geographical makeup of its little islands. Most islands have very little to-no vegetation. Given its seabird nesting grounds, strong storm surges or gusts could result in coastal erosion and damage to vegetation (affecting nesting grounds)	0.5	Minor infrastructure present in the form of the shelter for the 2 rangers that are stationed there for 6 months each year
Palmerston	32	1 x Palmerston Isl.	Settlements are spread across the island. Lush vegetation (palms and coconut) provides good shelter from the weather. The reef area and lush vegetation indicates that the island is well protected.	0.9	Damage would mainly be caused by falling debris from surrounding vegetation (during strong winds or storm surges).
Aitutaki	27	6	The biggest population is situated on the main island of Aitutaki with two major villages (Amuri & Arutanga). The main island has elevation, but a substantial amount of human settlement is focused around the coastal areas. There is also a significant amount of tourism, given the number of facilities (guest houses, rentals, villas etc.) that support the industry. Even with high reef area and a protected lagoon, there is potential for major damage during severe weather conditions.	0.7	Coastal communities within Amuri & Arutanga have high risks of infrastructure damage during severe weather events (especially communities located near the ocean-side on the western parts of Aitutaki. Loss would include, roads, buildings, businesses and potentially the airport to the north on Ootu peninsula.

	Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Coastal protection index (0-1)	Assets at Risk
Manuae and Te Au Otu	3	0	Uninhabited islands surrounded by reef flats, forereef and shallow lagoons. Both islands have good vegetation cover as well as high reef areas. Coastal erosion (sand shift) is visible via satellite imagery. Vegetation loss is possible as a result of severe weather conditions.	0.8	Not applicable
Takutea	1	0	Uninhabited island surrounded by reef flats, forereef and shallow lagoons. Island has good vegetation cover as well as high reef areas. Coastal erosion (sand shift) is visible via satellite imagery. Vegetation loss is possible as a result of severe weather conditions.	0.8	Not applicable
Atiu	1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast.	0.6	The most notable infrastructure is the airstrip due to its proximity to the beach. Other damages would include roads and jetties.
Mitiaro	1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation. Mangarei (village) would be the highest at risk of coastal damages given its proximity to shore (less than a 100m).	0.5	Infrastructure damage includes buildings and roads/utilities.

	Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Coastal protection index (0-1)	Assets at Risk
Mauke	1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast. Kimiangatau (village) would be the highest at risk of coastal damages given its proximity to shore (less than a 100m).	0.6	Infrastructure damage includes buildings and roads/utilities.
Rarotonga	5	1	Rarotonga has the highest risk in terms of population and development when it comes to natural disasters. Given its dense settlements to low lying areas, both infrastructure and livelihoods would be affected in the case of a natural disaster. The elevation map highlights areas that are prone to coastal flooding in terms of height above sea-level.	0.5	Utilities, buildings, roads, ports, jetties etc.
Mangaia	1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast. Oneroa (village) would be the highest at risk of coastal damages given its proximity to shore (less than a 100m).	0.6	Infrastructure damage includes buildings and roads/utilities from the Oneroa village and airstrip.

6.8.3 Value

The value of coastal protection provided by coral reefs can be estimated as the annualised expected value of storm damage that is avoided by having intact coral reefs versus a counterfactual case of degraded or absence of reefs.

The avoided damage costs method requires (i) determination of the extent of protection provided by natural ecosystems (i.e. coastal protection index), (ii) the population, property, and infrastructure at risk from erosion or flood damage, and (iii) the probability of damages given the estimated frequency of flood or erosion events. The value of the coastal protection ecosystem service is the costs from expected damages to homes, businesses, agriculture, or public infrastructure that will be avoided because of the presence of coral reefs.

Unfortunately, it has not been possible to obtain data for the Cook Islands on the location of property and infrastructure at risk from flood damage. We therefore make use of information from a global analysis of coral reef flood protection to make a rough estimate of the value of this service. Beck et al. (2018) use process-based flooding model to estimate the annual expected benefit of coral reefs for protecting people and property globally. Taking the results for the closest country reported in this study (Solomon Islands), we apply the estimated annual averted flood damages as a percentage of GDP (4%) to the Cook Islands. This gives an estimated annual value of coastal protection by coral reefs of NZD 23 million.[12]

[12] Annual value of coastal production = GDP*4%

6.8.4 Uncertainty

The results of this analysis are highly uncertain. One of the main challenges in assessing the role of coastal ecosystem in providing protection against storm damage coastal is the complexity of the process, incorporating many factors such as geomorphology of the coast and the presence of other ecosystems (Blacka et al., 2015; Splinter et al., 2017). The approach used to quantify a coastal protection index is exploratory and aims only to provide a broad indication of the coastal protection service provided by coral reefs.

The valuation of this service is derived from a transfer of information from a global analysis (Beck et al., 2018) and therefore lacks specificity to the context of the Cook Islands.

6.8.5 Sustainability

Reef ecosystems provide coastal protection benefits indefinitely as long as the ecosystems remain intact. The magnitude of the service could be increased in some instances by restoring degraded or damaged reefs.

Climate change and ocean acidification is expected to negatively impact coral reefs and threaten the sustainability of this ecosystem service (Brander et al., 2012). Climate change may also increase the intensity and severity of storms, increasing the importance of coastal protection services but also increasing the expected damage.

6.8.6 Distribution

The benefits of coastal protection accrue to anyone who owns, uses or is employed in property along coastal areas. The beneficiaries may be nationals, expatriate residents or visitors. Protection of public infrastructure, such as wharfs, marinas and roads, benefits everyone who uses that infrastructure and could benefit public finances through avoided repair costs.

6.9 Tourism

Marine and coastal ecosystems offer a variety of passive and active recreational activities that attract tourists to the Cook Islands. Recreational activities provided by the sea, reef, and beach include a wide range of pursuits including swimming, diving, snorkelling, charter fishing, fishing from the shore, recreational gleaning, kayaking, surfing, free-diving, beach activities and passive appreciation of beautiful coastal vistas. Visitors to the Cook Islands that participate in these activities can be described as engaging in marine and coastal tourism.

In this report we make the distinction between foreign visitors that engage in recreational activities in the marine and coastal environment (international tourism) and local residents who engage in the same activities (domestic recreation). This distinction is made because much domestic recreation involves non-market activities, while international tourism is more closely linked to charged activities and associated expenditures. This has implications for which valuation methods are applicable in each case and the extent to which value estimates can be made. This section addresses marine and coastal tourism by overseas visitors and section 6.10 addresses marine and coastal recreation by Cook Island residents.

Opportunities for tourism are dependent on two things: the natural and cultural amenities that people find attractive; and the man-made amenities that support travel, accommodation and recreation (Adamowicz et al., 2011). The extent to which tourism can be described as an ecosystem service depends on how much the visitor's activities depend on the natural ecosystem. Snorkelling, for example, is an activity that is almost entirely dependent on the state of the ecosystem. Individuals go snorkelling and appreciate snorkelling if there is clear water, and interesting coral and fish to look at. The more healthy and interesting coral and fish there are to see, the more likely tourists will be attracted to go snorkelling. Other activities are only partially linked to the condition and extent of the ecosystem. For example, tourists sitting at a beachside bar may enjoy a view of an unspoilt beach, but they also want a good drink and service. Furthermore, while they may be interested in the beach, they may be largely uninterested in what is going on beneath the water surface. The differences between activities complicate the calculation of tourism and recreation ecosystem services.

6.9.1 Identify

People from around the world treasure the unique marine and coastal ecosystems of the South Pacific. White sand beaches, coconut trees, warm turquoise water, brightly-coloured live coral and exotic fish — many people from higher latitudes dream of experiencing these tropical island ecosystems and make significant expenditures to do so. Natural beauty offers the opportunity to 'export' the service of tourism to foreigners.

The Cook Islands' marine and coastal ecosystems provide real and measurable benefits to international tourists and tourism businesses. These natural ecosystems, however, are only one part of the picture of attracting tourists. Tourism requires infrastructure, accommodation, transportation, communication systems and marketing. Prior to Covid-19, the Cook Islands had direct flights from New Zealand (Auckland), Australia (Sydney), and the United States (Los Angeles). Improvements to infrastructure are being implemented but any investment in the tourism sector would be undermined without protection of the natural resources that draw tourists to these picturesque tropical islands.

6.9.2 Quantify

Tourist visitor numbers to the Cook Islands have steadily increased over the past 20 years reaching a total of almost 129,000 in 2019 (see Figure 10). For the period 2014-2019, tourists accounted for 75% of total visitor arrivals in the Cook Islands. These tourist figures do not include visits for the purpose of weddings and honeymoons, which accounted for a further 18,610 visitors in 2019. The majority of visitors are from New Zealand (64%) followed by Australia (16%), North America (12%) and Europe (8%) – see Figure 11.

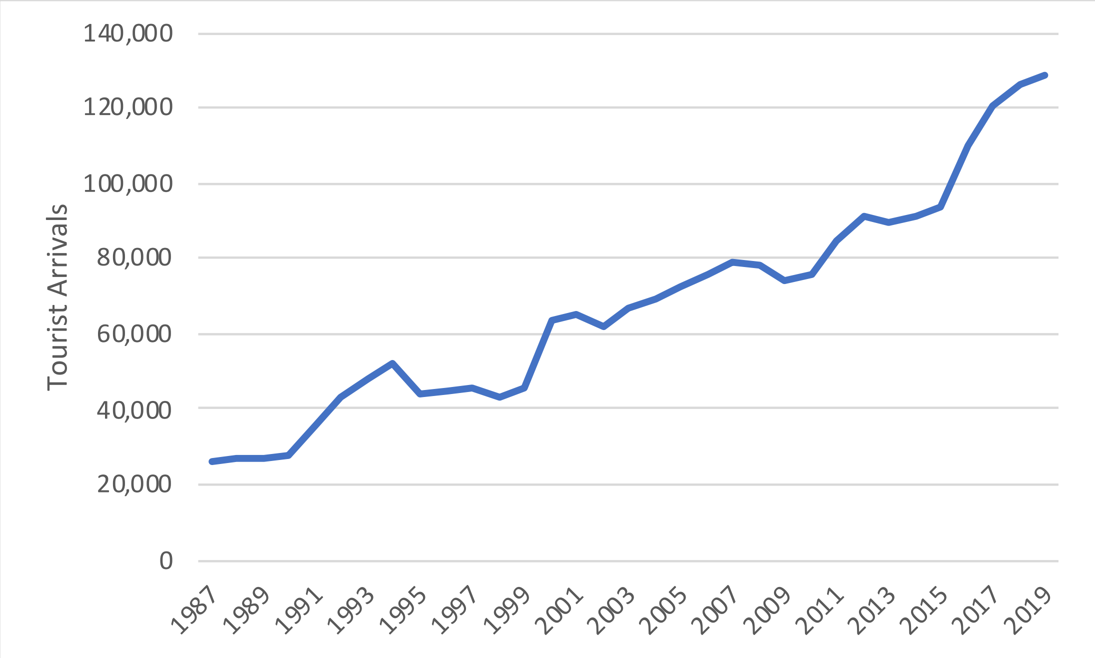

Figure 10. Tourist arrivals 1987-2019 (source data: MFEMb 2020)

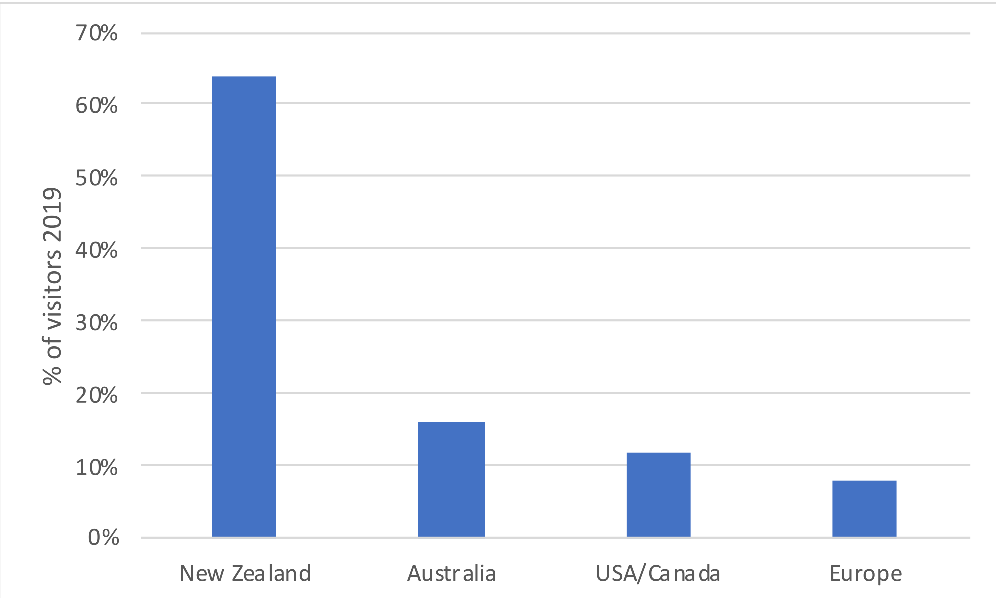

Figure 11. Tourist country of origin 2019 (source: NZTRI 2019a)

On average, visitors stayed for 8.5 nights. The destination of tourists within the Cook Islands is very concentrated on Rarotonga with almost all tourists visiting (98%); whereas 22% visited Aitutaki and 1% visited Atiu (NZTRI 2019a).

Figure 12 represents the participation rates of tourists in different activities during their stay in the Cook Islands. Marine and coastal activities form an important part of most tourist visits with 97% of tourists visiting the beach, 92% swimming, 82% snorkelling and 50% taking a lagoon cruise. Visitors also state high levels of satisfaction with the marine and coastal activities that they engage in. Visiting the beach receives the highest satisfaction rating (4.8 on a scale of 1-5) of all tourist activities – see Figure 13. In addition, "the environment, cleanliness and weather" is identified as the most attractive or appealing element of the Cook Islands experience – with just under half of visitors selecting this option (NZTRI, 2019b). There may, however, be room for improvement given that approximately 10% of visitors answered "rubbish and natural environment care" in response to the question "is there anything that could have improved your visit to the Cook Islands" (Sun and Milne, 2020).

Average visitor expenditure in 2019 was NZD 2,189 per person per visit. This is the amount that is received by the Cook Islands economy, i.e., excluding 60% expenditure prior to arrival that does not flow to the Cook Islands (e.g. expenditure on international flights). Breaking down the expenditure that does enter the Cook Islands economy, the average visitor spent NZD 816 prior to arrival and NZD 1,370 during their stay. Figure 14 represents average expenditure per person for the period 2014-2019.

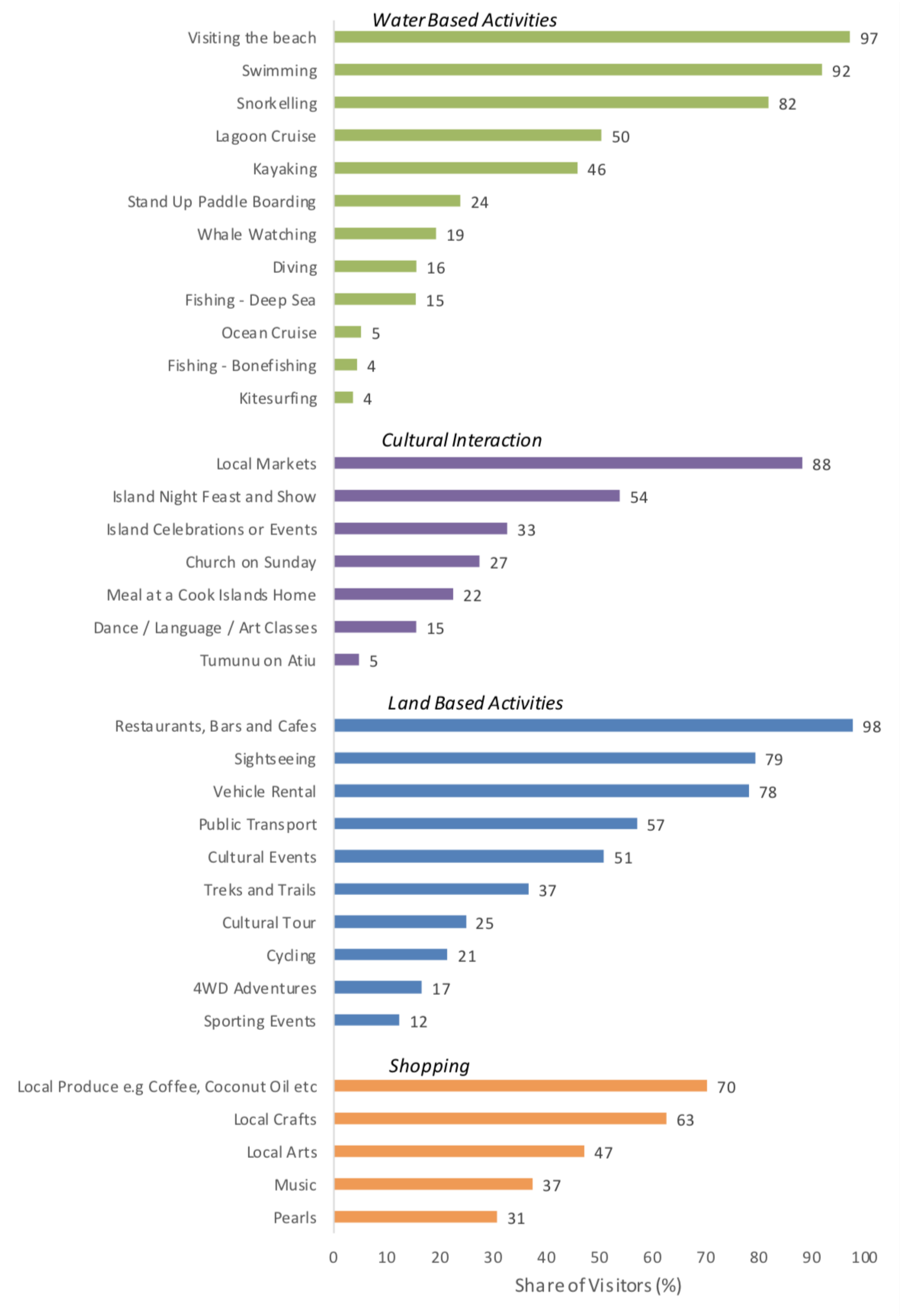

Figure 12. Visitor activity participation rates (source: NZTRI 2019b)

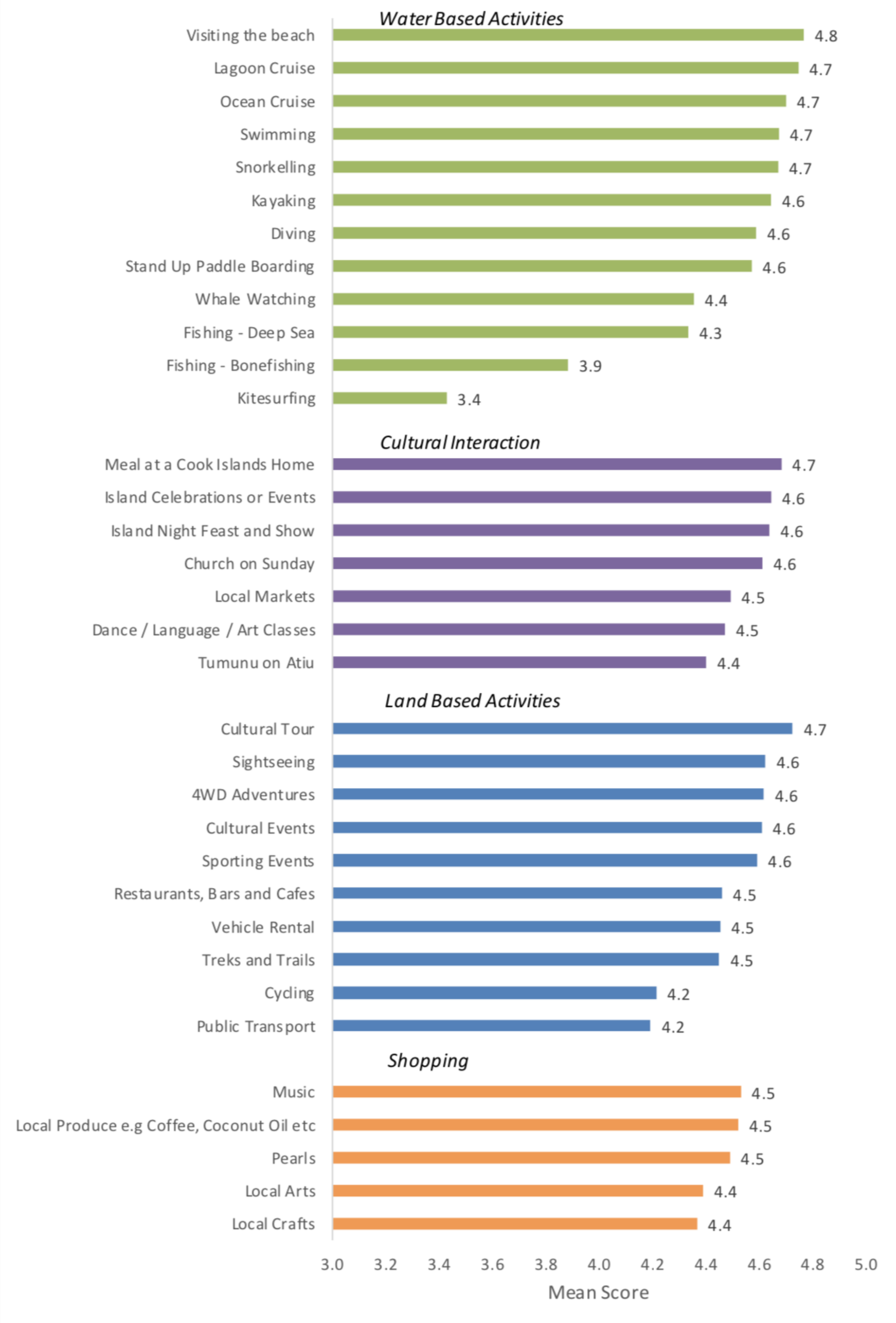

Figure 13. Satisfaction with visitor activities (source: NZTRI, 2019b)

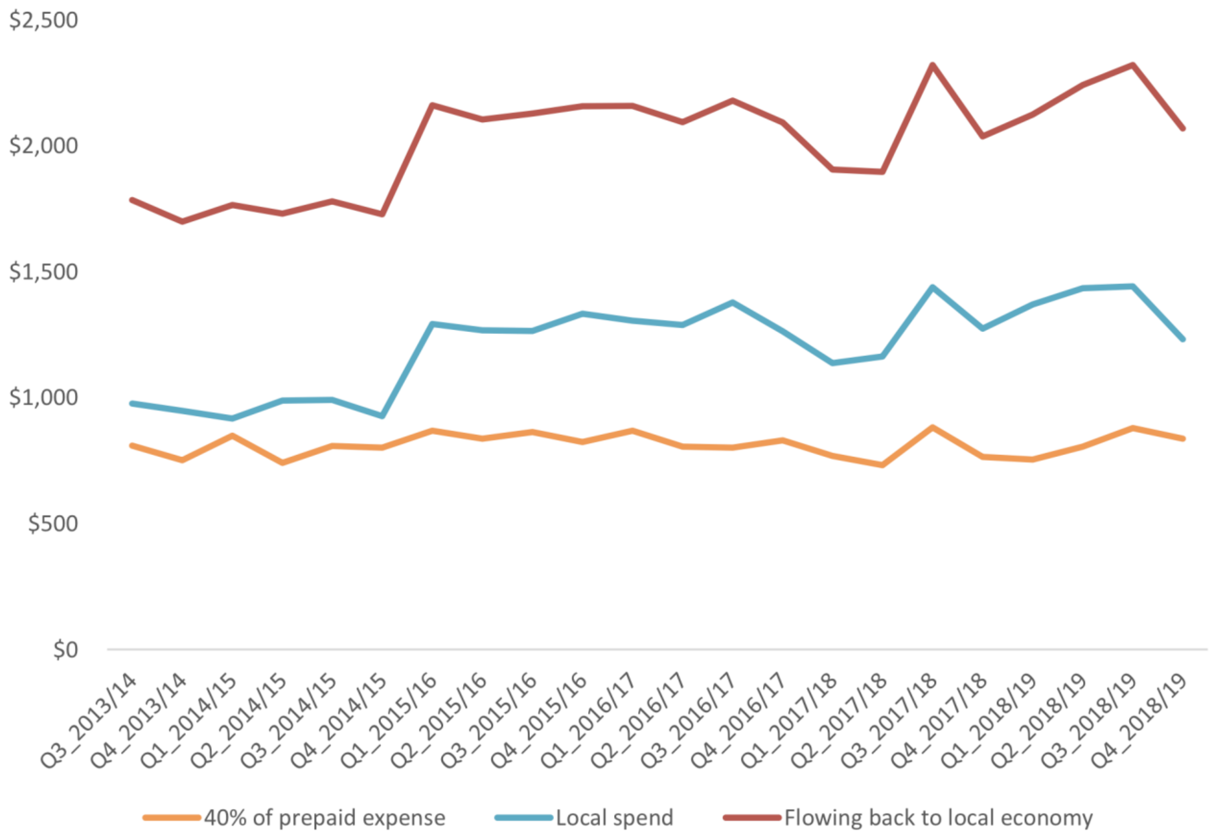

Figure 14. Expenditure per visitor NZD (source: NZTRI, 2019a)

6.9.3 Value

The benefits from marine and coastal tourism accrue to tourism providers (producers) and tourists (consumers). The benefits of a tourism activity to producers (their *profit*) are the service providers' *revenue* from tourist expenditure, minus the costs of providing the service. The benefit that tourists receive is measured as the difference between what they would be willing to pay for activities, travel, and lodging, and what they actually paid[13]. It is difficult to estimate consumer (tourist) benefits without conducting a detailed survey. Although the benefits to tourists accrue to foreign individuals, they are significant and important benefits that are closely related to health and beauty of natural ecosystems. Unfortunately, they cannot be estimated within the scope of this study.

Recreational activities that involve marketed services, such as diving and lagoon cruises, can be quantified by measuring direct expenditure by tourists. Other activities, such as swimming, beach activities and appreciation of coastal views, can only be quantified by indirect expenditure (i.e. transportation or equipment costs, or the *opportunity costs* of time spent participating) or by a *willingness-to-pay* survey. Both direct and indirect tourism expenditures contribute to the value of the ecosystem service.

[13] For example, if a tourist is willing to pay up to $ 200 for a two-tank dive, but the dive operator only charges $ 150, the tourist benefit is $ 50 ($ 200 – $ 150 = $ 50).

The gross value of tourism expenditures that accrue to the Cook Islands economy is estimated to be approximately NZD 282 million by multiplying the average visitor expenditure accruing to the Cook Islands by the number of vacation visitors (i.e., NZD 2,189 * 128,921 = NZD 282, 208,904). The difficulty in estimating the value of tourism as an ecosystem service, both to producers and consumers, lies in determining how much of the tourist expenditure is directly related to natural ecosystems. Reefs, beaches and marine biodiversity all contribute, to varying degrees, to the marketability of tourism activities. The degree of association between marine and coastal ecosystems and different tourist activities is the *ecosystem contribution factor* (ECF). The net producer value of the ecosystem services is calculated by multiplying the ECF by the difference between tourist expenditures and the tourism industry's costs.

$$Producer\ benefit_{\$} = (Total\ tourism\ revenue_{\$} - Tourism\ industry\ costs_{\$}) * \mathrm{ECF}$$

For some tourist expenditures, such as snorkelling, it may be safe to assume the ECF of healthy reefs and clean waters is 100%, meaning that the ecosystem is the sole factor contributing to the tourists' decision to go snorkelling. For less direct uses, such as beachside accommodation, there needs to be an estimate of how much the marine environment contributes to tourists' decisions and expenditures. Given the very high participation rate in marine and coastal activities and the top rating of the environment as the most appealing aspect of visiting the Cook Islands, we assume an ECF in the range 60-90%.

In the absence of information on the costs of providing tourism services, we make use of value-added ratios estimated elsewhere in the Pacific. Value-added ratios of 25% for Guam (Van Beukering et al. 2007b) and 40% for the Northern Mariana Islands (Van Beukering et al. 2006) are used to estimate the net producer benefit of gross tourism *revenue*. We use the 25% *value-added* ratio as a conservative estimate of net producer benefits. Table 13 shows the estimated annual *producer surplus* (*profit*) from tourism that is attributable to marine and coastal ecosystems. For example, the estimated lower bound net benefit is computed as the total expenditure multiplied by the lower bound ECF and by the lower bound valued added ratio (282,208,904*0.6*0.25 = 42,331,336)

Table 13: Gross tourism expenditure and net tourism benefit from marine/coastal ecosystems

Total expenditure (NZD/year)	282,208,904
ECF - low	0.6
ECF - high	0.9
Value Added ratio – low	0.25
Value Added ratio - high	0.4
Net benefit - low (NZD/year)	42,331,336
Net benefit - high (NZD/year)	101,595,206

The Government of the Cook Islands also benefits from marine and coastal tourism through tax revenue. The value added tax (VAT) rate in the Cook Islands is 15%. Using the total gross expenditure related to marine and coastal ecosystems, we estimate that the Government of the Cook Islands receives approximately NZD 25-38 million per year in revenue from this ecosystem service.

The *total economic value* of an ecosystem service is the sum of the producer, government, and consumer benefits. The producer and government benefits are estimated to be approximately NZD 68-140 million with a mid-point of just under NZD 104 million. The lower bound is calculated as the sum of low producer surplus and low government revenue (i.e., NZD 42.3 million + NZD 25 million); and the upper bound is calculated as the sum of high producer surplus and high government revenue (i.e., NZD 101.6 million + NZD 38 million). The benefits that tourist visitors receive from marine and coastal ecosystems have not been quantified in this study. Estimating the consumer benefits would require a detailed survey of tourist preferences, behaviour and willingness to pay. The values above should be regarded as lower bound estimates of the value of this service.

6.9.4 Uncertainty

There are a number of sources of uncertainty in the estimated value of marine and coastal tourism.

Each tourist site has different environmental attributes that influence producer earnings and tourist benefits, such as quantity of fish to see while snorkelling or the quality of water for swimming. Tourist benefits are also influenced by man-made amenities and proximity to transportation or other tourist sites. To determine the effect that environmental attributes alone have on tourism requires models that control for non-environmental factors (Adamowicz et al. 2011).

The greatest uncertainty in the estimates comes from the *ecosystem contribution factor* and the *value-added* ratio. By providing a range for the ECF (60-90%) we can be fairly certain that the true value lies within these low and high bounds. The *value-added* ratios (25-40%) are based on previously published work and is not specific to the Cook Islands. Some businesses may earn higher profits; others may have profits even lower than 25%.

As with most of the ecosystem services in this study, we presume that the estimates of producer and government benefit underestimate the total social benefit of the ecosystem service because they do not include the consumer benefits. Producer and government benefits, however, may be most relevant because they accrue to the Cook Islands, whereas consumer benefits accrue to foreign tourists. Lastly, there are some costs associated with collecting value added tax which have not been subtracted, so the tax *revenue* benefits are slight overestimates.

6.9.5 Sustainability

If managed responsibly, tourism can be a lucrative and sustainable ecosystem service. Because tourists generally seek out healthy ecosystems, tourism can create an incentive to protect and even rehabilitate marine ecosystems. If tourists are educated properly, the direct impacts to ecosystems from snorkelling, diving, swimming and beach walking may be minimal. However, tourism can also increase demand for energy, infrastructure and imported goods, and generate waste. Fulfilling these demands can lead to degradation of the ecosystems the tourists were originally attracted to.

6.9.6 Distribution

The benefits of tourism are split among government (tax revenue), business owners, employees, and the tourists themselves. Producer profit (local businesses) and government revenue are benefits received within the Cook Islands. Some tourism businesses are foreign-owned, so some of their profits may be re-invested in the Cook Islands and some will be transferred to the owners' home countries. Employment in the tourism sector, although a cost to tourism businesses, is a benefit to Cook Islanders. Many businesses and jobs are indirectly linked to the tourism sector through supply chains that ultimately feed tourist services (e.g., local produce that is used in tourist hotels and restaurants). International tourism revenue is money flowing into the Cook Islands from overseas and, like other exports, generates positive foreign exchange.

6.10 Recreation

6.10.1 Identify

In a similar way to international tourism, domestic marine and coastal recreation depends on the availability and quality of natural areas; and infrastructure and service investments, such as transportation systems, beach and boat access areas, and businesses that facilitate use and appreciation of natural areas. When Cook Island residents participate in market-based activities, such as joining commercial dive trips, staying in hotels and eating in restaurants, the domestic recreation ecosystem service is much the same as international tourism. However, recreation activities that do not involve any payment also have *economic value* by contributing to human wellbeing in the form of consumer surplus. Even activities as simple as enjoying watching the tide come in is a marine ecosystem service. It is necessary, however, to use different methods to quantify and value these activities.

While some ecosystem services such as fisheries are rival (meaning the more one individual benefits from the ecosystem service, the less others may benefit), recreation is generally a public good. Public goods are non-rival activities for which one individual's benefit does not impinge on another's benefit. This means that although per capita benefits may be small in magnitude, the total benefit to all Cook Islanders could be quite large.

6.10.2 Quantify

The household survey was used to ask respondents how often they, or members of their household, engage in a range of leisure/recreational activities. The responses are summarised in Figure 15. It is notable that almost all households engage in some form of recreational activity in the marine and coastal environment. As expected, some recreational activities are more widely practiced than others. Walking/relaxing at the beach, relaxing in the lagoon and swimming in the sea are enjoyed by almost all households. Between 60-70% of households engage in these activities at least a few times per month. Snorkelling is also a popular recreational activity with just over 40% of households engaging in this activity at least a few times per month. Other activities are niche sports that relatively few households engage in. For example, jet skiing, kite surfing and triathlons are practiced regularly by only a small proportion of households and the majority have never tried them.

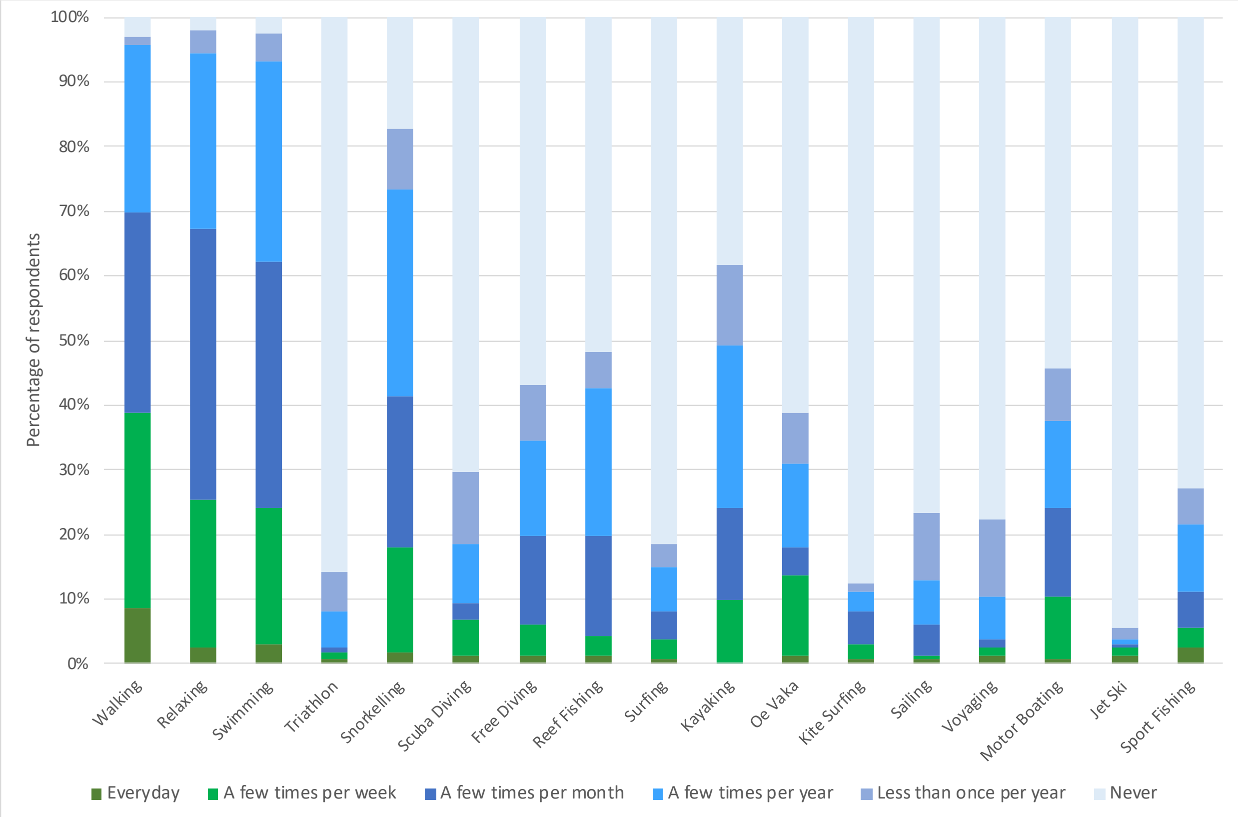

Figure 15. Household participation in recreational activities

6.10.3 Value

Many of the recreational activities that Cook Islanders engage in require only limited expenditure, meaning that there is limited producer surplus made from supplying recreation activities or equipment and that the bulk of economic value derived from this ecosystem service is consumer surplus. The valuation of this ecosystem service therefore requires the use of a stated preference valuation method to measure what people are willing to pay for marine and coastal recreation.

The choice experiment in the household survey is used to estimate household willingness to pay to ensure the quality of the marine environment that enables recreational activities. Conversely, the value can be interpreted as a willingness to accept a degradation in water quality that would limit recreational use of the marine and coastal environment. Multiplying the median annual household willingness to pay for an improvement in marine water quality from ‘low’ to ‘high’ (NZD 1,049) by the number of households in the Cook Islands (4,435), we estimate the total annual value of marine and coastal recreation to be NZD 4.65 million, with a 95% confidence interval of NZD 1.44 – 10.46 million.

Table 14: Willingness to pay for recreational use of the marine and coastal environment

	Median	Low CI	High CI
Willingness to pay (NZD/household/month)	87	27	197
Willingness to pay (NZD/household/year)	1,049	325	2,358
Willingness to pay (NZD/year)	4,653,025	1,440,665	10,459,859

6.10.4 Uncertainty

The valuation of domestic recreation is characterised by high uncertainty, as reflected by the very wide confidence interval for the estimated value. There are several sources of uncertainty underlying this valuation including the small and non-representative sample for the MESV household survey and a number of biases associated with stated preference methods. The choice experiment frames a hypothetical situation in which respondents can choose to pay for improvements in the quality of the marine and coastal environment. The hypothetical nature of the donation might result in the respondent not taking the payment amounts seriously or ignoring it when making their choices. It is also possible that respondents behave strategically and overstate their preferences for environmental quality in order to influence the results of the valuation and subsequently policy decisions.

6.10.5 Sustainability

As a non-rival public good, domestic recreation in the marine and coastal environment is a sustainable ecosystem service. It is possible, however, that recreational activities can cause pollution and degradation to marine and coastal areas. Investments in measures such as public awareness campaigns and waste removal systems may be required to assure sustainability.

6.10.6 Distribution

Most of the benefits from domestic recreation accrue to Cook Island households that enjoy recreation activities. Some associated expenditures may create benefits to businesses that supply equipment for recreation (e.g., snorkelling and scuba gear, fishing gear, kayaks, boats etc.) but most of the benefits go to the individuals participating in marine and coastal recreation and leisure activities. These activities may generate broader benefits to society by supporting the health and happiness of individuals, and they may generate support for government infrastructure investment and nature conservation.

6.11 Existence and bequest values for biodiversity

6.11.1 Identify

Ecosystems can have value to people even if they do not directly or indirectly receive benefits from them. Individuals may simply appreciate knowing that ecosystems are healthy, and that species are not going extinct. This is the *existence value* of ecosystems. Some individuals may also want to preserve ecosystems so that they are available for future generations (*bequest value*).

6.11.2 Quantify

The *existence value* of nature's ecosystems and the value of preserving nature for future generations (*bequest value*) are *non-use values*. In general, these values are not reflected in markets or national accounts, meaning that they are not easily visible to decision-makers, which in turn can lead to poor resource management decisions (Cesar et al., 2003). Although difficult to measure, *existence* and *bequest values* are components of the *total economic value* of an ecosystem.

The amount of welfare that an individual or household derives from the knowledge that specific natural ecosystems continue to exist and/or will be available to future generations may be small but in sum across all individuals or households that benefit, the welfare implications can be large (Loomis et al., 2000; Daubert and Young, 1981).

Since there are no markets for these services nor any associated markets that can reveal their value, the only way to quantify the scale and importance of such services is to ask people what they are worth using *stated preference* economic survey methods. To obtain quantitative measures of Cook Islanders' preferences for environmental conservation, we make use of the discrete choice experiment (DCE) method (described in section 5.4).

6.11.3 Value

The choice experiment in the household survey is used to estimate household willingness to pay to ensure the diversity of native and migratory marine animal species. Multiplying the median annual household willingness to pay for an improvement in marine biodiversity from 'low' to 'high' (NZD 1,205) by the number of households in the Cook Islands (4,435), we estimate the total annual value of marine and coastal recreation to be NZD 5.35 million, with a 95% confidence interval of NZD 1.52 – 12.7 million. It is notable that the estimated existence and bequest value is higher than that of direct use recreational value.

Table 15: Willingness to pay for conservation of biodiversity

	Median	Low CI	High CI
Willingness to pay (NZD/household/month)	100	29	234
Willingness to pay (NZD/household/year)	1,205	344	2,811
Willingness to pay (NZD/year)	5,345,417	1,527,414	12,467,317

6.11.4 Uncertainty

The valuation of existence and bequest values for biodiversity is characterised by high uncertainty, as reflected by the very wide confidence interval for the estimated value. There are several sources of uncertainty underlying this valuation including the small and non-representative sample for the MESV household survey and a number of biases associated with stated preference methods. The choice experiment frames a hypothetical situation in which respondents can choose to pay for conservation of biodiversity in the marine and coastal environment. The hypothetical nature of the donation might result in respondents not taking the payment amounts seriously and ignoring it when making their choices. It is also possible that respondents behave strategically and overstate their preferences for environmental quality in order to influence the results of the valuation and subsequently policy decisions.

6.11.5 Sustainability

The quality of the Cook Islands marine and coastal environment that supports biodiversity is currently high. There are, however, several threats that could impact biodiversity in the future including climate change, ocean acidification, marine pollution, waste, land-based runoff and potentially seabed mineral extraction.

6.11.6 Distribution

The non-use value of preserving biodiversity of the Cook Islands marine and coastal environment is estimated only for Cook Island residents. It is possible, however, that people living in other parts of the world also hold values for the continued existence of the biodiversity present in the Cook Islands, such as rare, threatened or endemic species, and would potentially be willing to pay for its conservation.

6.12 Other values

Below are examples of marine ecosystem services that may be found in the Cook Islands but have not been included in this study.

6.12.1 Cultural values

Cultural values refer to the “non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience” (MEA, 2005). This could include cultural heritage, traditional education, spiritual, religious or moral values, or the value of a sense of place. A cultural connection to the ocean is fundamental to the people of the Cook Islands. A range of traditions bind people to marine and coastal areas.

6.12.2 Carbon sequestration

Carbon dioxide (CO_2) in the atmosphere causes a greenhouse effect that results in changes to the global climate, sea temperatures, and sea levels, which may have deleterious effects on Pacific Island countries in particular. In addition, CO_2 in the atmosphere is absorbed by seawater resulting in lower sea pH levels and reduced availability of carbonate ions for marine animals that make calcium carbonate shells and skeletons (e.g. shellfish and corals). This process is termed ocean acidification.

Several marine and coastal ecosystems (mangroves, wetlands, seagrasses and phytoplankton) remove CO_2 from the atmosphere and store it in their fibres, in the soil and in the ocean substrate (Howard et al. 2014). This ecosystem service is called carbon sequestration, and refers to carbon that is removed from the atmosphere and/or prevented from release into the atmosphere.

The natural growth processes of seagrass, mangroves, plankton and other plants absorb carbon from the air. Some carbon is released back into the atmosphere during cell respiration, some is added to the plant’s biomass, and some is deposited into the soil or ocean substrate. Carbon stored in the biomass of mature plants is relatively constant, but can be released into the atmosphere if the plants are killed and decay or burned. Carbon stored near the soil surface may be released over time if left unvegetated, or released quickly if disturbed (Murray et al. 2011). Both the rate at which carbon is added to biomass and substrate, and the potential release of stored carbon are important. Together they represent the net CO_2 removed from the atmosphere and prevented from release into the atmosphere.

The amount of carbon that is captured and removed from the atmosphere by different ecosystems can be quantified in terms of a net rate of sequestration. The net amount of carbon sequestered by an ecosystem in a given time period is the sum of the rate of sequestration of each species and the release of stored carbon (Howard et al. 2014).

The magnitude of this ecosystem service is directly related to the prevalence of the ecosystems that sequester and store carbon. There are three main categories of organisms that sequester carbon in tropical Pacific marine and coastal environments: mangrove, seagrass and sea algae. These are not present or common in the Cook Islands. Salt marshes also sequester and store carbon, but are uncommon in the Pacific. Coral reef may sequester carbon under certain circumstances, but reefs are generally a net emitter of carbon dioxide (Ware et al., 1991; Suzuki and Kawahata, 2004).

Ocean phytoplankton consume CO_2 and sequester substantial amounts of carbon in ocean sediments (Reibesell, 2004; Avelar et al., 2017). The amount of phytoplankton, their carbon sequestering properties, and the influence humans have on phytoplankton and ocean sediments are all very difficult to quantify[14]. The carbon sequestering service of phytoplankton is not quantified in this study. We note, however, that disturbance of marine sediment may result in release of stored carbon and should be considered as a potential external cost of seabed mining.

6.12.3 Research and education

Although recognition of the value of biodiversity has grown significantly in the past two decades (most notably by the creation of the United Nations Convention on Biological Diversity), biodiversity remains extremely difficult to quantify and value at the national scale. One method to quantify the value of biodiversity is to evaluate the amount of public funds that are redistributed to help protect biodiverse areas. The unique biodiversity found in marine and coastal environments in the Pacific attracts investment in research and conservation from around the world. Furthermore, these biodiverse ecosystems offer education opportunities to students of all ages, and investment from schools and universities. This interest in studying and protecting biodiversity attracts grants, scholarships and aid that benefit Pacific Island countries.

Domestic and international government expenditures represent a redistribution of resources, not a true *economic benefit*, but foreign aid from wealthier countries, international organisations, non-governmental organisations and private donors contributes significantly to the economies of most Pacific Island countries.

6.12.4 Bio-prospecting

Bio-prospecting is the process of discovering and commercialising new products from natural sources. Marine resources, particularly in areas with high biodiversity such as coral reefs, or unique ecology such as deep-sea thermal vents, may house potentially marketable products or elements that lead to marketable products. If there is currently no exploitation of these products, bio-prospecting represents an *option value,* that is, the resources have value today because we have the option for new discoveries or commercialisation in the future. The pharmaceutical industry is an important *beneficiary* of bio-prospecting. The fair and equitable distribution of benefits arising from bio-prospecting back to Cook Islanders is considered under the CBD's Nagoya Protocol on Access and Benefit Sharing (ABS).

6.12.5 Bioremediation

Coastal and marine ecosystems can play an important role in filtering and remediating polluted water. By transforming toxic pollutants into non-hazardous forms, microbes (bacteria, fungi, yeast, and algae) provide biological waste processing (Bonaventura & Johnson, 1997). This ecosystem service is called bioremediation.

Island communities are generally considered highly vulnerable to Ciguatera fish poisoning (Skinner et al., 2011) and this is a common health problem in the Cook Islands (IAMAT, 2020). This form of food poisoning is caused by eating fish contaminated by ciguatoxins, which are found in fish intestines and livers and cannot be destroyed by any method of food preparation.

[14] Research on the sequestration and storage process of phytoplankton is ongoing, and trials are being conducted to attempt to increase the rate of sequestration (Reibesell 2004; Riebesell et al. 2007).

In addition, the taste, texture, colour or smell of the food is not altered, making its detection difficult (Skinner et al., 2011).

Through the bioaccumulation process both herbivore fish and larger predatory fish can be contaminated with ciguatoxins, therefore any reef fish can be contaminated. The most affected fish, however, are bass, barracuda, grouper, red snapper and parrotfish among others (IAMAT, 2020). Bioremediation is seen as crucial to combatting this form of food poisoning in the Pacific. The process of using living organisms, such as microbes and bacteria, as purifying agents can help to counteract chemical pollution to restore marine and coastal polluted ecosystems (Alava, 2019).

The bioremediation service can be provided by a variety of marine ecosystems (Palazón et al., 2018) and seagrass in particular is recognised as playing an important role in removing microbiological contaminants (Norland et al., 2016; Lamb et al., 2017). Seagrasses and aquatic macrophytes produce natural biocides and it is observed that coral reefs that fringe seagrass meadows show significantly less impact from coral and fish disease (Lamb et al., 2017).

This ecosystem service is potentially important in the Cook Islands where currently there is no treatment system of sewage being pumped/piped to the sea. Individual septic tanks are the main treatment 'system', which suffer from seepage and leaking of waste/nutrients that in turn end up in marine and coastal ecosystems, resulting in deterioration of environmental quality and damage to human health. The provision of the bioremediation service results in lower rates of food poisoning and associated treatment costs and welfare losses. An alternative perspective on the value of this service is that without bioremediation, it would be necessary to invest in additional wastewater treatment. Alternative options for waste water treatment have been assessed under the Mei Te Vai Ki Te Vai (MTVKTV) project (https://www.totatouvai.co/mei-te-vai-ki-te-vai).

6.12.6 Handicrafts

Marine ecosystems provide materials for many handicrafts. A variety of seashells are used to make traditional and contemporary jewellery. Pearls are harvested from wild and commercially cultivated oysters.

Handicrafts that are sold earn vendors a *resource rent*, the same as any market good that depends on 'free' natural inputs. The *resource rent* is the *net value* of the product after the value of labour time and other production costs have been subtracted. Handicrafts that are used at home have an avoided-cost value, meaning that they are worth what the household does not have to spend to purchase the items.

6.12.7 Mariculture

Mariculture relies on the ecosystem service of good quality seawater and appropriate habitat for growth of the cultured species. Part of the value of harvested products comes from the features and processes of the natural marine habitat.

6.12.8 Aesthetic value

Many people appreciate marine and coastal areas for their natural beauty. The aesthetic value of marine and coastal areas is an ecosystem service that appears as a component of different activities and is not typically paid for directly. The *economic value* of aesthetic areas is often revealed through associated markets, in particular tourism, recreation and housing. Where this service is a component of market-based tourism and recreation (e.g. sailing, surfing, staying at beach resorts), the value has already been captured by measurement of those ecosystem services. In other words, aesthetic value is a component of the tourism value of marine and coastal ecosystems. As a component of non-market tourism and recreation, a study (survey) of individuals' preferences and *willingness-to-pay* for coastal vistas would be required.

Aesthetic value also appears in the housing market. Individuals' housing decisions can reveal their preference for the aesthetic beauty of coastal areas by the difference between what they are willing to pay to live in coastal areas in contrast to inland areas. The *hedonic pricing method* is used to statistically analyse how the aesthetic value of coastal areas is embedded in the value of coastal property. This economic method requires substantial amounts of data about properties and their rental and sales prices, making it difficult to conduct in small island developing states (Van Beukering et al., 2007a).

6.13 Supporting services: ecological processes and biological diversity

Some *ecosystem functions* do not directly benefit humans, but may be instrumental in supporting other *ecosystem functions*. Basic *ecosystem functions* such as photosynthesis, nutrient cycling, soil and sand formation and other so-called *supporting ecosystem services* are intermediate services to many human behaviours and activities. The ocean has an important role in the production of oxygen (phytoplankton produce half of the earth's oxygen), nitrogen fixation, waste assimilation and regulating global temperatures and climate (Samonte-Tan et al., 2010; Galland et al., 2012; NOAA 2012). While some of these *ecosystem functions* may not benefit humans directly, they underpin life on earth. None of the values identified and discussed in this study can exist without well-functioning ecological processes (such as production, growth, recruitment) underpinned by biological and abiotic diversity of marine ecosystems (MEA, 2005). Their value, however, is often carried over into direct or final ecosystem services. To avoid double counting the value of supporting ecosystem services, ecosystem service valuation should focus on the final human benefits coming from the end-products of *ecosystem functions* (Boyd and Banzhaf, 2007; Fisher et al., 2009). In so much as these *supporting services* facilitate more tangible ecosystem services, their value is captured in the valuation of those services; to value them separately from the end user values would be double counting their value.

6.14 Summary of values

The net economic values of the ecosystem services estimated in this study are summarised in Table 16 and Figure 16. The total annual value of marine and coastal ecosystem services to the Cook Islands in 2019 is estimated to be just over NZD 191 million.

Table 16: Summary of the net economic value of marine and coastal ecosystem services in the Cook Islands

Ecosystem service	Beneficiaries	Economic value (NZD/year)
Subsistence fisheries	Domestic households	3,661,182
Commercial fisheries	Domestic and foreign operators	50,389,917
Trochus	Domestic households	55,690
Pearls	Domestic businesses	300,000
Sand and coral aggregate	Domestic households	164,656
Seabed minerals[1]	Government; Foreign operators	-
Coastal protection	Domestic households and businesses	23,016,000
Tourism	Domestic businesses	103,711,772
Recreation	Domestic households	4,653,025
Biodiversity existence values	Domestic households	5,345,417
Total		191,297,660

[1]The potential future net value of seabed mineral extraction has not been estimated in this study.

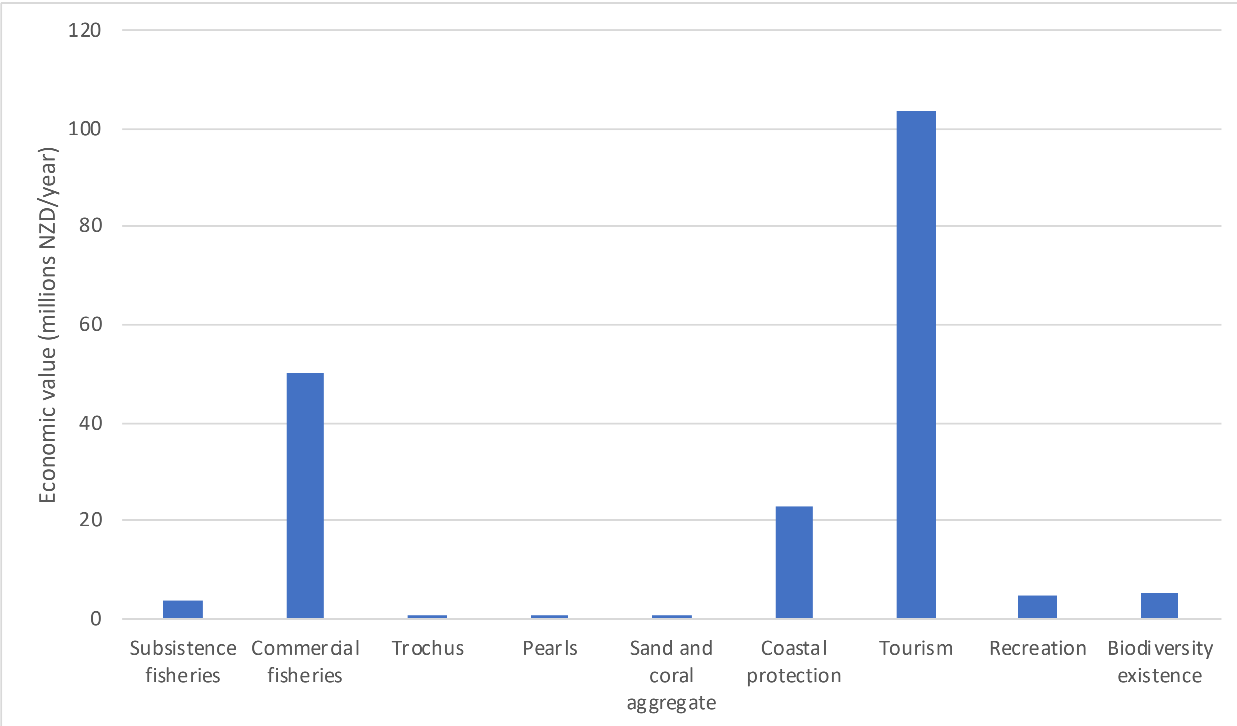

Figure 16. Economic value of marine and coastal ecosystem services in the Cook Islands

7 Summary and discussion

The information in Chapter 6 allows us to better understand the human benefits of the Cook Islands' marine and coastal environment. The information can, and should, be used to compare the types, magnitude and distribution of benefits from different marine resources.

Knowing who receives the benefits of each ecosystem service identifies incentives to change or maintain management practices, helps prioritise allocation of government resources, and helps decision-makers understand who will benefit or suffer from a change in policy or resource use. For example, to a large extent, commercial fisheries do not directly benefit average households in the Cook Islands, but they do generate *revenue* for government operations that benefits Cook Islanders. Government has an incentive to manage the fisheries industry to provide that *revenue*, even though the impact on Cook Island households is more ambiguous.

With an EEZ more than 7,000 times larger than the country's land area, it is no surprise that the Cook Islands' marine resources provide enormous benefits. Marine and coastal ecosystems serve as a vast asset of natural wealth that delivers a continuous stream of benefits. It is important to avoid unsustainable withdrawals from this account.

The values presented in Chapter 6 for fisheries and tourism mostly represent benefits to *producers*, meaning those who harvest, extract or earn *revenue* from a resource. Coastal protection values represent benefits to all residents, businesses and visitors; and recreation values are benefits to domestic households. Government benefits are included where they are significant. *Revenue* from taxes or fees levied on Cook Island businesses and residents represents a redistribution of benefits within the Cook Islands and is not a true *economic value*. When the tax or fee *revenue* derives from foreign visitors or foreign businesses, it does represent a true *economic value* to the Cook Islands. The costs of administering licences and collecting fees must, however, be subtracted from *gross revenue*.

The ecosystem service of subsistence fishing provides benefits to many Cook Island households, particularly rural and poor households. Although subsistence fishing is not the main economic activity of many households, it does supply at least some food needs for around 30% of families and can be viewed as a means of reducing expenditure on food.

Exploration for seabed mineral extraction is already providing revenue to the Government of the Cook Islands, but no direct benefits to Cook Island households or the economy yet. A comprehensive Deep-Sea Mining Act paves the way for oversight and benefit-sharing if mining operations occur in the future. The magnitude of threats to marine and coastal ecosystem services cannot yet be quantified or valued but must be considered.

Tourism is an important industry in the Cook Islands that depends largely on healthy marine and coastal ecosystems. Prior to Covid-19, tourism was increasing, and may eventually return to 2019 levels after the pandemic. Tourism benefits a variety of businesses and their employees and provides government tax *revenue*. Tourism can be a sustainable ecosystem service if managed and regulated. The current limitation on tourism due to the pandemic is a useful juncture to consider what levels and forms of tourism are sustainable and desirable for the Cook Islands.

Other marine and coastal ecosystem services include carbon sequestration, mariculture, handicrafts, bioremediation, cultural identity and aesthetic beauty. These services have not been quantified by this study because of a lack of data, but they provide benefits to the Cook Islands and the rest of the world and could be investigated through further research and data collection in the future.

8 Caveats and considerations

The important qualitative and quantitative information presented in Chapter 6 can be compromised by the need to provide a simple and brief summary. Busy political leaders need clear and concise summaries of research, but over-simplification of ecosystem service research can lead to misinterpretation and inappropriate generalisation of the results. The benefits quantified and valued above should be considered individually. Policy-makers must resist the urge to aggregate these values for the following reasons:

i. Each value represents a slightly different type of benefit. Gross values, *net values*, employment, government *revenue* and *consumer surplus* are all units for measuring benefits but should not be combined together, despite the fact that they are all represented in New Zealand Dollars (NZD).
ii. Values represent current use, not sustainable use, equitable use, or maximum potential benefit. Some ecosystem services may be unsustainable at current rates of exploitation, while others may have potential for greater expansion.
iii. Some ecosystem services complement each other, others compete. For example, growth in tourism may adversely impact the inshore finfish and invertebrate fishery, whereas protection of coral reefs may increase coastal protection and increase inshore fisheries productivity.

These three qualifications must be considered any time the results are used, reproduced, or updated.

The valuation results in Chapter 6 are mostly estimates of *producer surplus* derived from each ecosystem service and are therefore only partial measures of the full contribution ecosystems make to human wellbeing. The full economic value includes benefits to consumers, producers, and government. It is important to recognise that consumer surplus has only been estimated to a limited extent in this report (for recreation and non-use values).

Another important consideration is the relationship between ecosystem service values and human population density. Ecosystem service value is directly correlated to the number of people who receive benefits. Healthy, intact ecosystems often exist where there are few people. No matter how productive the ecosystem, the values of ecosystem services in remote places are often quite low, because there are few humans that benefit from them. More densely populated areas may have higher ecosystem service values because there are more beneficiaries but this does not imply that the ecosystems in such areas are more productive, in better condition or being used sustainably. Because of this phenomenon, it is very important to analyse the ecological sustainability of current resource use to assess whether the status-quo values can be maintained, or if they can be expected to decrease over time.

9 Recommendations and future directions

Because of the large scope of this project (national valuation of many services), no single topic has been analysed in great detail. Each subsection in Chapter 6 should serve as a base of information about each ecosystem service that the Cook Islands can choose to explore more deeply as the need arises.

Problematic data gaps are discussed in the Quantify section for each ecosystem service. If the Cook Islands wishes to use economic information about ecosystem benefits, the gaps in data should be evaluated first to enable more rigorous assessment of the benefits.

This study is a step towards a national process of recognising the human benefits of natural ecosystems. Further valuation of ecosystem services should be targeted to the specific applications above, leading to more equitable and sustainable management of the Cook Islands' marine assets. More generally, the Cook Islands should continue to make steps towards accounting for natural capital in order to ensure the sustainable prosperity of the country.

A significant limitation of this work is the lack of scenario analysis. Ecosystem services are valued according to their current use, usually using data from 2019 or averages from the past five to ten years. This does not describe the *potential* value of the ecosystem. Scenario analysis considers different options of resource use and management and quantifies the ecosystem services that people would receive under the different scenarios. This is a type of *cost-benefit analysis* using the values of ecosystem services to quantify the costs and benefits. The Cook Islands may wish to use this report as a starting point for these types of analyses.

At the national scale, ecosystem service valuation could support the adoption of the System of Environmental-Economic Accounting (SEEA). Although more detailed assessments of the national value of ecosystem services will be required, this report could serve as a *baseline* for natural capital accounting. The Cook Islands may wish to build on this report to institute the SEEA and account for the value of the country's natural resources.

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11 Appendix I: Glossary

Avoided damage cost valuation method: A cost-based valuation technique that estimates the value of an ecosystem service by calculating the damage that is avoided to infrastructure, property and people by the presence of ecosystems.

Baseline: The starting point from which the impact of a policy or investment is assessed. In the context of ecosystem service valuation, the baseline is a description of the level of ecosystem service provision before a policy or investment intervention.

Beneficiary: A person that benefits from the provision of ecosystem system services.

Bequest value: the value to the current generation of knowing that something (e.g. pristine coral reef) will be available to future generations.

Choice modelling: Choice modelling attempts to model the decision process of an individual or segment in a particular context. Choice modelling may be used to estimate non-market environmental benefits and costs. It involves asking individuals to make hypothetical trade-offs between different ecosystem services.

Constant prices: Prices that have been adjusted to the price level in a specific year. Constant prices account for inflation and allow values to be compared across different time periods.

Consumer surplus: The difference between what consumers are willing to pay for a good and its price. Consumer surplus is a measure of the benefit that consumers derive from the consumption of a good or service over and above the price they have paid for it.

Contingent valuation: Contingent valuation is a survey-based economic technique for the valuation of non-market resources, such as environmental preservation or the impact of contamination. It involves determining the value of an ecosystem service by asking what individuals would be willing to pay for its presence or maintenance.

Cost-benefit analysis: An evaluation method that assesses the economic efficiency of policies, projects or investments by comparing their costs and benefits in present value terms. This type of analysis may include both market and non-market values and accounts for opportunity costs.

Direct use value: The value derived from direct use of an ecosystem, including provisioning and recreational ecosystem services. Use can be consumptive (e.g. fish for food) or non-consumptive (e.g viewing reef fish).

Discount rate: The rate used to determine the present value of a stream of future costs and benefits. The discount rate reflects individuals' or society's time preference and/or the productive use of capital.

Discounting: The process of calculating the present value of a stream of future values (benefits or costs). Discounting reflects individuals' or society's time preference and/or the productive use of capital. The formula for discounting or calculating present value is:

present value = future value/(1+r)n, where r is the discount rate and n is the number of years in the future in which the cost or benefit occurs.

Economic activity analysis: An analysis that tracks the flow of dollars spent within a region (market values). Both economic impact and economic contribution analysis are types of economic activity analysis.

Economic activity: The production and consumption of goods and services. Economic activity is conventionally measured in monetary terms as the amount of money spent or earned and may include 'multiplier effects' of input costs and wages

Economic benefit: the net increase in social welfare. Economic benefits include both market and non-market values, producer and consumer benefits. Economic benefit refers to a positive change in human wellbeing.

Economic contribution: The gross change in economic activity associated with an industry, event, or policy in an existing regional economy.

Economic cost: A negative change in human wellbeing.

Economic impact: The net changes in new economic activity associated with an industry, event, or policy in an existing regional economy. It may be positive or negative.

Economic value: i) The monetary measure of the wellbeing associated with the production and consumption of goods and services, including ecosystem services. Economic value is comprised of producer and consumer surplus and is usually described in monetary terms. Or ii) The contribution of an action or object to human wellbeing (social welfare).

Ecosystem contribution factor: The degree of association between marine and coastal ecosystems and different tourist activities.

Ecosystem functions: The biological, geochemical and physical processes and components that take place or occur within an ecosystem.

Ecosystem service approach: A framework for analysing how human welfare is affected by the condition of the natural environment.

Ecosystem service valuation: Estimation of the net human benefits of an ecosystem service, usually in monetary units.

Ecosystem services: The benefits that ecosystems provide to people. This includes services (e.g. coastal protection) and goods (e.g. fish).

Ecosystem service flow: The quantity of ecosystem services that are provided by ecosystems and used by beneficiaries in a given period of time (usually a year).

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem stock: The bio-physical extent and condition of ecosystems that exist within a geographic area.

Evaluate: To assess the overall effect of a policy or investment.

Evaluation: The assessment of the overall impact of a policy or investment. Evaluations can be conducted before or after implementation of a policy or investment.

Existence value: The value that people attach to the continued existence of an ecosystem good or service, unrelated to any current or potential future use.

Factor cost: Total cost of all factors of production consumed or used in producing a good or service.

Financial benefit: A receipt of money to a government, firm, household or individual.

Financial cost: A debit of money from a government, firm, household or individual.

Free-on-board: The taxable value for each fished species. This value theoretically represents the market value of the product, although this is not always the case in practice.

Future value: A value that occurs in future time periods. See also present value.

Geographic Information Systems (GIS): An information system that captures, stores, manages, analyses and presents data that is linked to a geographic location.

Green accounting: The inclusion of information on environmental goods and services and/or natural capital in national, sectoral or business accounts.

Gross revenue: Money income that a firm receives from the sale of goods or services without deduction of the costs of producing those goods or services. Gross revenue from the sale of a good or service is computed as the price of the good (or service) multiplied by the quantity sold.

Gross value: The total amount made as a result of an activity.

Hedonic pricing method: A method for pricing ecosystem services. Hedonic price models assume that the price of a product reflects embodied characteristics valued by some implicit or shadow price.

Indirect use value: The value of ecosystems services that contribute to human welfare without direct contact with the elements of the ecosystem, for example regulating services such as plants producing oxygen or coral reefs providing coastal protection.

Inflation: A general rise in prices in an economy.

Instrumental value: The importance of something as a means to providing something else that is of value. For example, a coral reef may have instrumental value in reducing risk to human life from extreme storm events.

Intermediate costs: The costs of inputs or intermediate goods that are used in the production of final consumption goods. For example, the cost of fishing gear used to catch fish is an intermediate cost to the harvest and sale of fish.

Intrinsic value: The value of something in and for itself, irrespective of its utility to something or someone else. Not related to human interests and therefore cannot be measured with economic methods.

Marginal value: The incremental change in value of an ecosystem service resulting from an incremental change (one additional unit) in the quantity produced or consumed.

Market value: The amount for which a good or service can be sold in a given market.

Negative externality: Negative externalities occur when the consumption or production of a good causes a harmful effect to a third party.

Net revenue: Monetary income (revenue) that a firm receives from the sale of goods and services with deduction of the costs of producing those goods and services. Net revenue from the sale of a good is computed as the price of the good multiplied by the quantity sold, minus the cost of production.

Net value: The value remaining after all deductions have been made.

Nominal: The term 'nominal' indicates that a reported value includes the effect of inflation. Prices, values, revenues etc. reported in 'nominal' terms cannot be compared directly across different time periods. See also real and constant prices.

Non-use value: The value that people gain from an ecosystem that is not based on the direct or indirect use of the resource. Non-use values may include existence values, bequest values and altruistic values.

Opportunity cost: The value to the economy of a good, service or resource in its next best alternative use.

Option value: The premium placed on maintaining environmental or natural resources for possible future uses, over and above the direct or indirect value of these uses.

Present value: A value that occurs in the present time period. Present values for costs and benefits that occur in the future can be computed through the process of discounting (see discount rate). Expressing all values (present and future) in present value terms allows them to be directly compared by accounting for society's time preferences.

Producer surplus: The amount that producers benefit by selling at a market price that is higher than the minimum price that they would be willing to sell for. Producer surplus is computed as the difference between the cost of production and the market price. Value-added, profit, and producer surplus are similar measures of the net benefit to producers. Although they differ slightly, the terms are used synonymously for this report to represent one compoment of economic value.

Profit: The difference between the revenue received by a firm and the costs incurred in the production of goods and services. Value-added, profit and producer surplus are similar measures of the net benefit to producers. Although they differ slightly, the terms are used synonymously for this report to represent economic value.

Purchasing power parity adjusted exchange rate: An exchange rate that equalises the purchasing power of two currencies in their home countries for a given basket of goods.

Purchasing power parity: An indicator of price level differences across countries. Figures represented in purchasing power parity represent the relative purchasing power of money in the given country, accounting for variance in the price of goods. Typically presented relative to the purchasing power of US dollars in the United States.

Real: The term ‘real’ indicates that a reported value excludes or controls for the effect of inflation (synonymous with constant prices). Reporting prices, values, revenues etc. in ‘real’ terms allows them to be compared directly across different time periods. See also nominal and constant prices.

Regulating services: A category of ecosystem services that refers to the benefits obtained from the regulation of ecosystem processes. Examples include water flow regulation, carbon sequestration and nutrient cycling.

Rent: Any payment for a factor of production in excess of the amount needed to bring that factor into production (see also producer surplus and resource rent).

Replacement cost method: A valuation technique that estimates the value of an ecosystem service by calculating the cost of human-constructed infrastructure that would provide same or similar service to the natural ecosystem. Common examples are sea walls and wastewater treatment plants that provide similar services to reefs, mangroves, and wetland ecosystems.

Resource rent: The difference between the total revenue generated from the extraction of a natural resource and all costs incurred during the extraction process (see also producer surplus). Refers to profit obtained by individuals or firms because they have unique access to a natural resource.

Revenue: Money income that a firm receives from the sale of goods and services (often used synonymously with gross revenue).

Social cost of carbon: The social cost of carbon is an estimate of the economic damages associated with a small increase in carbon dioxide (CO2) emissions, conventionally one tonne, in a given year. This dollar figure also represents the value of damages avoided for a small emission reduction (i.e. the benefit of a CO2 reduction).

Stated preference survey method: A survey method for valuation of non-market resources in which respondents are asked how much they would be willing to pay (or willing to accept) to maintain the existence of (or be compensated for the loss of) an environmental feature such as biodiversity.

Supporting services: A category of ecosystem services that are necessary for the production of all other ecosystem services. Examples include nutrient cycling, soil formation and primary production (photosynthesis).

Total economic value: i) All marketed and non-marketed benefits (ecosystem services) derived from any ecosystem, including direct, indirect, option and non-use values, or ii) The total value to all beneficiaries (consumer, producer, government, local, foreign) from any ecosystem service.

Use value: Economic value derived from the human use of an ecosystem. It is the sum of direct use, indirect use and option values.

User cost: The cost incurred over a period of time by the owner of a fixed asset as a consequence of using it to provide a flow of capital or consumption services; the implications of current consumption decisions on future opportunity. User cost is the depreciation on the asset resulting from its use.

Utilitarian value: A measure of human welfare or satisfaction. Synonymous with economic value.

Valuation: The process or practice of estimating human benefits of ecosystem services or costs of damages to ecosystem services, represented in monetary units.

Value: The contribution of an action or object to human wellbeing (social welfare).

Value-added: The difference between cost of inputs and the price of the produced good or service. Value-added can be computed for intermediate and final goods and services. Value-added, profit, and producer surplus are similar measures of the net benefit to producers. Although they differ slightly, the terms are used synonymously for this report to represent economic value.

Welfare: An individual's satisfaction of their wants and needs. The human satisfaction or utility generated from a good or service.

Willingness-to-accept: The minimum amount of money an individual requires as compensation in order to forego a good or service.

Willingness-to-pay: The maximum amount of money an individual would pay in order to obtain a good or service.

12 Appendix II: Stakeholder consultation questionnaire

Cook Islands Marine Ecosystem Service Valuation (MESV) Consultation

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Stakeholder consultation on Marine Ecosystem Service Valuation (MESV) study
Kia Orana

You are invited to participate in the initial consultation process for the Cook Islands Marine Ecosystem Service Valuation (MESV) study. This study is part of the Cook Islands Ridge to Reef (R2R) project supported by the UNDP with funding from Global Environment Facility (GEF) in partnership with the Cook Islands Government. The study will support the Marae Moana Coordination Office to better protect and sustainably manage the marine resources of the Cook Islands.

The purpose of this initial stakeholder consultation is threefold:

1. To inform stakeholders of the Marine Ecosystem Service Valuation (MESV) study
2. To collect feedback on the ecosystem services included in the study
3. To identify and collect relevant data for the economic valuation of marine resources

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Your details
1) Your name*

____

2) Organisation*

____

3) Email address*

____

Information on the Marine Ecosystem Service Valuation (MESV) study

The objective of the MESV study is to provide information on the economic contribution of marine biodiversity and ecosystem services to the wellbeing of Cook Islanders, now and into the future, in order to support better long-term decision making and management of marine resources including the development of Marine Spatial Plans for the Marae Moana.

The results of the study will be available at the end of November 2020.

The study is conducted by Te Ipukarea Society (TIS) and Dr. Luke Brander from the University of Hong Kong (HKU) on behalf of the National Environment Service for the Ridge to Reef project.

Marine ecosystem services included in the study

Ecosystem services – the benefits that humans receive from ecosystems – include direct uses of marine resources (e.g. fish and other seafood for consumption or sale; recreation and tourism activities; seabed minerals, etc.), indirect uses (e.g. coral reefs provide protection from storm damage; filtration of waste water, etc.) and cultural uses (e.g. sense of place and identity, etc.).

The MESV study will attempt to measure the importance of marine ecosystem services to the wellbeing of Cook Islanders.

An initial list of marine ecosystem services is provided below. We ask for your feedback on this list and to indicate whether we are missing an important service or have included something that is not relevant. We may follow up for further details.

4) Please rate each of the following marine ecosystem services in terms of importance to the Cook Islands (0 = not at all important; 5 = very important)*

	0	1	2	3	4	5
Subsistence fishing/gleaning	( )	( )	( )	( )	( )	( )
Commercial fishing	( )	( )	( )	( )	( )	( )
Pearl farming	( )	( )	( )	( )	( )	( )
Trochus harvest	( )	( )	( )	( )	( )	( )
Sand and coral mining	( )	( )	( )	( )	( )	( )
Seabed minerals	( )	( )	( )	( )	( )	( )
Filtration of land-based nutrients and wastewater	( )	( )	( )	( )	( )	( )
Filtration of saltwater (desalination)	( )	( )	( )	( )	( )	( )
Protection from storms and coastal flooding	( )	( )	( )	( )	( )	( )
Carbon sequestration and storage	( )	( )	( )	( )	( )	( )

Tourism (international visitors)	( )	( )	( )	( )	( )	( )
Recreation (Cook Islanders)	( )	( )	( )	( )	( )	( )
Landscape/ seascape value (aesthetics, photography)	( )	( )	( )	( )	( )	( )
Research and education	( )	( )	( )	( )	( )	( )
Cultural identity and sense of place	( )	( )	( )	( )	( )	( )
The existence of biodiversity, endemic and migratory species	( )	( )	( )	( )	( )	( )

5) Are there any other marine ecosystem services that you think should be considered in the MESV study?

____

Data for the economic valuation of marine resources

The MESV study requires data to estimate the economic values of marine resources. We want to use this stakeholder consultation to start the process of identifying and collecting relevant data. Please indicate what data you have for the ecosystem services in the form below. We will follow up for further details.

6) Please indicate what data you have or know of for the marine ecosystem services listed below

Subsistence fishing/gleaning: ____

Commercial fishing: ____

Pearl farming: ____

Trochus harvest: ____

Sand and coral mining: ____

Seabed minerals: ____

Filtration of land-based nutrients and wastewater: ____

Filtration of saltwater (desalination): ____

Protection from storms and coastal flooding: ____

Carbon sequestration and storage: ____

Tourism (international visitors): ____

Recreation (Cook Islanders): ____

Landscape/ seascape value (aesthetics, photography): ____

Research and education: ____

Cultural identity and sense of place: ____

The existence of biodiversity, endemic and migratory species: ____

Comments

7) If you have any comments or suggestions for the MESV project, please use the box below

____

Thank You!

Meitaki ma’ata for your inputs!

Please feel free to share this survey with others you think would be able to contribute knowledge and information.

13 Appendix III: Household survey questionnaire

Cook Islands Marine Ecosystem Service Valuation (MESV) Household Survey

Kia Orana

You are invited to participate in this household survey for the Cook Islands Marine Ecosystem Service Valuation (MESV) study. This study is part of the Cook Islands Ridge to Reef (R2R) project supported by the United Nations Development Programme (UNDP) with funding from Global Environment Facility (GEF) in partnership with the Cook Islands Government. The study will support the Marae Moana Coordination Office to better protect and sustainably manage the marine resources of the Cook Islands.

The purpose of this household survey is to collect information on Cook Islanders' use of the marine environment and the values they place on it, including:

Harvest of fish and other resources

Leisure and recreation

Cultural practices

Conservation of biodiversity, native and migratory species

Threats to the marine environment

Note that the purpose of this survey and study is NOT to collect donations.

The survey will take around 20 minutes or less to complete.

The survey is conducted by Te Ipukarea Society (TIS) and Dr. Luke Brander from the University of Hong Kong (HKU) on behalf of the Ridge to Reef project for the Cook Islands Government. If you have any questions regarding this survey, please contact info@tiscookislands.org

Instructions

When answering the questions, please keep the following in mind:

Answer on behalf of your whole household (family members living under the same roof)

All data collected by this survey will be treated as confidential

Rough estimates of quantities and times are sufficient

There are no right or wrong answers - we only want your honest opinion

For the questions regarding harvesting, recreation and cultural practices, consider your activities in the past year

The questions regarding donations to a conservation fund are hypothetical and we will NOT ask you to make actual donations

---

Harvest of fish and other resources

1) Do you (including other members of your household) harvest the following marine resources? Consider your activities in the past year.

[ ] Ocean fish (including flying fish)

[ ] Reef fish

[ ] Shellfish

[ ] Other - Write In (Required): ____*

[ ] None

2) How often do you (including other members of your household) go fishing for ocean fish?*

( ) 1-6 times per year

( ) 7-11 times per year

( ) 1 time per month

( ) 2-3 times per month

( ) 1 time per week

( ) 2-3 times per week

( ) 4-6 times per week

( ) Everyday

( ) Other - Write In (Required): ____*

3) How much ocean fish do you (including other members of your household) catch per fishing trip?*

( ) 1-5 kg

( ) 5-10 kg

( ) 10-20 kg

( ) 20-50 kg

( ) 50-100 kg

( ) More than 100 kg

( ) Other - Write In (Required): ____*

4) How often do you (including other members of your household) go fishing for reef fish?*

( ) 1-6 times per year

( ) 7-11 times per year

( ) 1 time per month

( ) 2-3 times per month

( ) 1 time per week

( ) 2-3 times per week

( ) 4-6 times per week

( ) Everyday

( ) Other - Write In (Required): ____*

5) How much reef fish do you (including other members of your household) catch per fishing trip?*

( ) 1-5 kg

( ) 5-10 kg

( ) 10-20 kg

( ) 20-50 kg

( ) 50-100 kg

( ) More than 100 kg

( ) Other - Write In (Required): ____*

6) How often do you (including other members of your household) collect shellfish?*

( ) 1-6 times per year

( ) 7-11 times per year

( ) 1 time per month

( ) 2-3 times per month

( ) 1 time per week

( ) 2-3 times per week

( ) 4-6 times per week

( ) Everyday

( ) Other - Write In (Required): ____*

7) How much shellfish do you (including other members of your household) harvest per trip?*

( ) 1-5 kg

( ) 5-10 kg

( ) 10-20 kg

( ) 20-50 kg

( ) 50-100 kg

( ) More than 100 kg

( ) Other - Write In (Required): ____*

8) Has the abundance of the marine resources that you harvest changed during the past 5-10 years? *

( ) Increased a lot

( ) Increased a bit

( ) No change

( ) Decreased a bit

( ) Decreased a lot

9) Are there any marine resources that you used to harvest, or that you are aware of, that are no longer available?*

( ) Yes

( ) No

10) Please name the marine resources that are no longer available

____

Leisure and Recreation

11) How often do you or members of your household engage in the following leisure/recreational activities*

	Every-day	A few times per week	A few times per month	A few times per year	Less than once per year	Never
Walking/relaxing on the beach	( )	( )	( )	( )	( )	( )
Relaxing in the lagoon	( )	( )	( )	( )	( )	( )
Swimming in the sea	( )	( )	( )	( )	( )	( )
Triathlon	( )	( )	( )	( )	( )	( )
Snorkelling	( )	( )	( )	( )	( )	( )
Scuba diving	( )	( )	( )	( )	( )	( )
Free diving and spear fishing	( )	( )	( )	( )	( )	( )
Reef fishing	( )	( )	( )	( )	( )	( )

Surfing/Boogie boarding	( )	( )	( )	( )	( )	( )
Canoeing/kayaking /SUP for leisure	( )	( )	( )	( )	( )	( )
Canoeing/Oe Vaka as a sport	( )	( )	( )	( )	( )	( )
Kite surfing	( )	( )	( )	( )	( )	( )
Sailing	( )	( )	( )	( )	( )	( )
Traditional voyaging	( )	( )	( )	( )	( )	( )
Motor boat	( )	( )	( )	( )	( )	( )
Jet ski	( )	( )	( )	( )	( )	( )
Sport fishing	( )	( )	( )	( )	( )	( )

Cultural Practices

12) Do you use the coast and/or sea for any cultural/religious practices or special occasions?*

( ) Yes

( ) No

13) Please describe the cultural/religious practices or special occasions that you use the coast and/or sea for:*

____

14) Do you use materials (e.g. shells, fish) collected from the coast or sea for any cultural/religious practices or special occasions?*

( ) Yes

( ) No

15) Please describe the cultural/religious practices or special occasions that you use materials collected from the coast and/or sea for:*

____

16) Do you use any plants/materials collected from the coast or sea for medicinal purposes?*

( ) Yes

( ) No

17) Please describe the plants/materials that you collect for medicinal purposes*

____

18) Are there any materials or (e.g. shells, fish etc.) that you would never harvest?*

( ) Yes

( ) No

19) Please describe the materials (e.g. shells, fish) that would you never harvest and explain why*

____

Conservation of biodiversity, native and migratory species

20) Have you, or other members of your household, donated any money for conservation of the marine environment in the last 12 months?*

( ) Yes

( ) No

21) If yes, how much money (in NZ$)?*

____

22) Have you, or other members of your household, volunteered your time for conservation of the marine environment in the last 12 months (e.g. fund raising, beach clean up)?*

( ) Yes

( ) No

23) If yes, how much time (in days)?*

____

24) In principle, would you be willing to contribute money to support conservation of marine biodiversity, native and migratory species in the Cook Islands?*

( ) Yes

( ) No

Choice questions

Note that this survey does NOT ask you to actually donate money. Your responses to the following questions will simply help us understand some (not all) of the values you place on the marine environment.

One way for us to better understand the values that Cook Islanders place on the marine environment is to ask what people would be prepared to pay for conservation measures. For example, we may ask what would you be prepared to pay per month to a dedicated conservation fund that is used for a range of activities such as improved waste water treatment, fisheries management, protection of endangered species etc.

In the following questions you will be asked to choose between conservation options that are defined by the following features:

Fish and shellfish abundance. The abundance of fish and shellfish that can be caught
- described as low, moderate or high

Water quality for recreation. The quality of coastal water that can be used for leisure/recreation - described as low, moderate or high

Marine biodiversity. The diversity of native and migratory marine animal species - described as low, moderate or high

Cost to you per month. The money amount in NZ$ that you would be willing to pay each month through a donation to an administered fund dedicated to marine conservation in the Cook Islands. Note that there is no intention to ask you for this money.

Choice question instructions

On the next page you will be asked to choose between three options.

Options A and B represent two different possible outcomes based on additional conservation measures funded by your monthly contribution.

Option C shows the “business as usual” outcome with no additional conservation effort beyond what is already being done.

It is likely that none of the options represent your ideal outcome so please choose the option that you prefer out of the three. Please consider carefully how much extra money you could actually afford to contribute each month and where that money would come from, given the other expenses in your monthly budget.

In total you will be shown 6 choice cards and asked to choose one option on each card. Note that Options A and B are different on each card and Option C remains the same.

Choice Card 1

25) Please choose ONE of the three options

The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

*

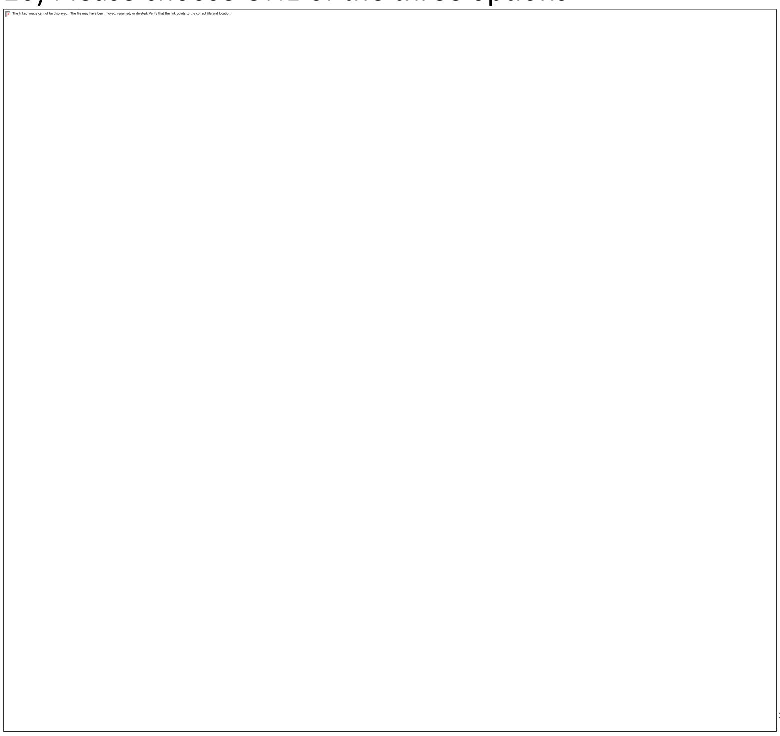
( ) Option A

( ) Option B

( ) Option C

Choice Card 2

26) Please choose ONE of the three options



*

( ) Option A

( ) Option B

( ) Option C

Choice Card 3

27) Please choose ONE of the three options

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*

( ) Option A

( ) Option B

( ) Option C

Choice Card 4

28) Please choose ONE of the three options

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*

( ) Option A

( ) Option B

( ) Option C

Choice Card 5

29) Please choose ONE of the three options

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*

( ) Option A

( ) Option B

( ) Option C

Choice Card 6

30) Please choose ONE of the three options

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*

( ) Option A

( ) Option B

( ) Option C

Concern for the marine environment

85) How concerned are you about the following potential threats to the marine environment in the Cook Islands?*

	Don't know	Not at all con-cerned	Not con-cerned	Neut-ral	A bit con-cerned	Very con-cerned
Climate change	( )	( )	( )	( )	( )	( )
Ocean acidification	( )	( )	( )	( )	( )	( )
Overfishing inshore	( )	( )	( )	( )	( )	( )
Plastic waste	( )	( )	( )	( )	( )	( )
Sewage, wastewater and storm runoff	( )	( )	( )	( )	( )	( )
Seabed mineral exploration	( )	( )	( )	( )	( )	( )
Industrial offshore fishing	( )	( )	( )	( )	( )	( )

About you and your household

The following questions are for statistical purposes only

86) Age?*

( ) Under 18

( ) 18 - 25

( ) 26 - 35

( ) 36 - 45

( ) 46 - 55

( ) 56 - 65

( ) Over 65

87) Gender?

( ) Female

( ) Male

( ) Other

( ) Decline to answer

88) What is the highest level of formal education you have completed?

( ) Primary School

( ) Secondary

( ) High School

( ) Technical/ Vocational/ Diploma

( ) University Degree

( ) Other - Write In: ____

( ) None

( ) Decline to answer

89) How many members in your household (including yourself)?*

Children/teenagers (17 years old and below):

____

Adults (18-64 years old): ____

Adults (65 years old and above): ____

90) Please indicate your monthly household income (in NZ$)*

( ) Under $100

( ) $100 - $500

( ) $500 - $1,000

( ) $1,000 - $3,000

( ) $3,000 - $6,000

( ) $6,000 - $10,000

( ) Over $10,000

( ) Decline to answer

Comments

91) If you have any comments or suggestions for the MESV project, please use the box below

____

92) If you would like to receive a copy of the Cook Island Marine Ecosystem Service Valuation report, please leave your email address here:

____

If you have any questions regarding this survey or the Cook Islands Marine Ecosystem Service Valuation study, please contact info@tiscookislands.org

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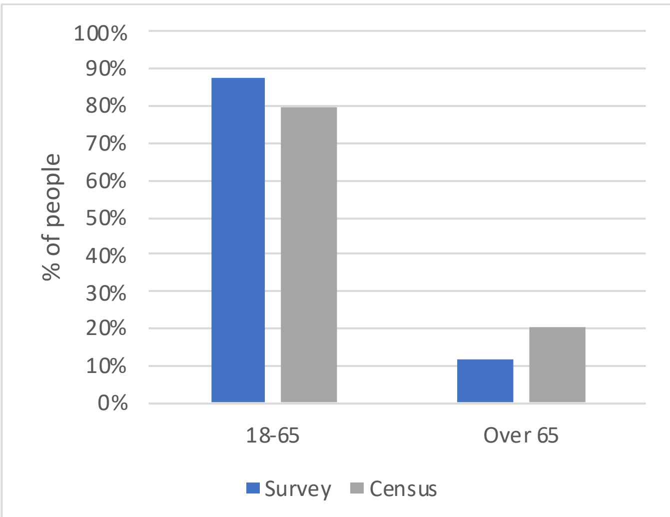
Thank You!

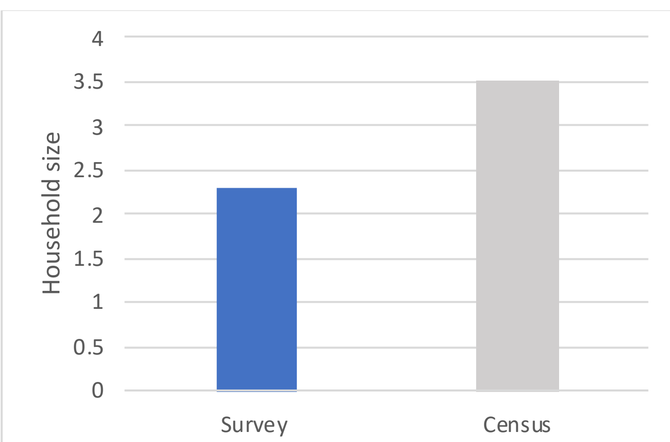
Meitaki ma'ata for your inputs!

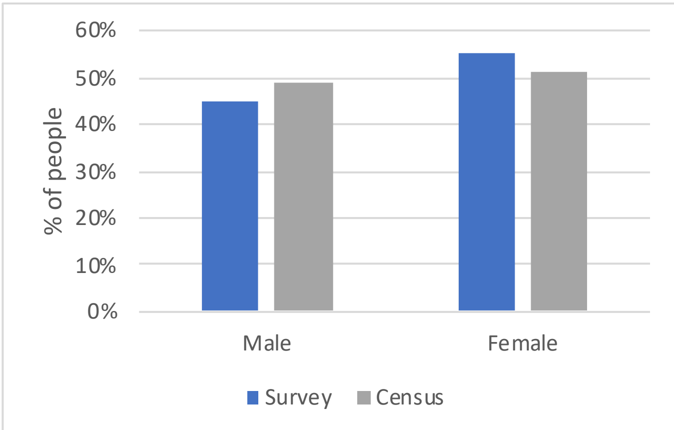
Please feel free to share this survey with others who you think would like to contribute their knowledgee and information using the link or QR code below:
https://www.surveygizmo.eu/s3/90262821/Cook-Islands-MESV-Household-Survey

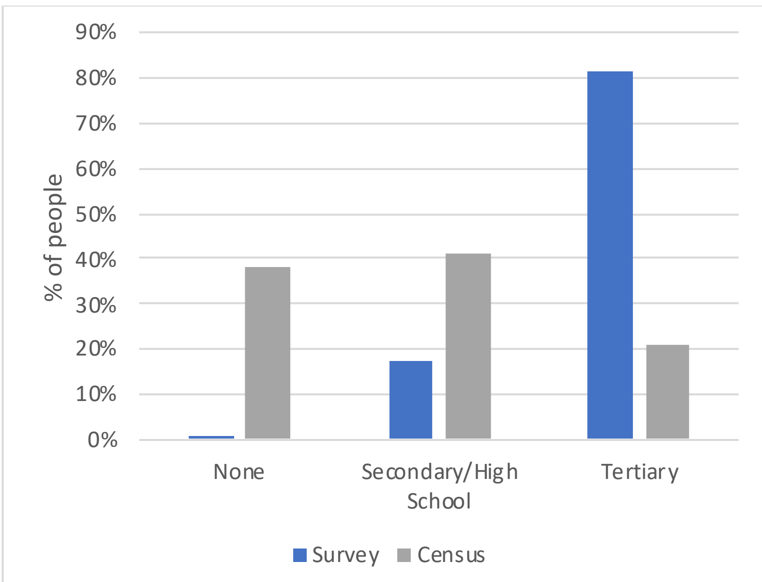
14 Appendix IV: Household survey sample description

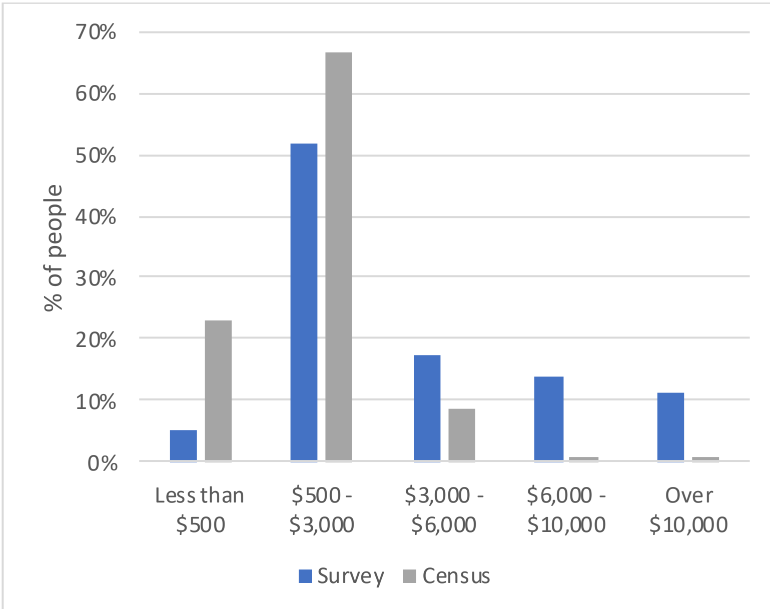
The socio-demographic characteristics of the sample for the MESV household survey are summarised and compared in the Figures below with the Cook Island population characteristics obtained from the 2016 census (CISO 2018). It should be noted that the survey sample over-represents respondents/households of smaller size, higher income, younger age, and higher education. This is attributable to the convenience sampling approach and web-based survey, through which it is harder to reach older, lower income, lower education households.





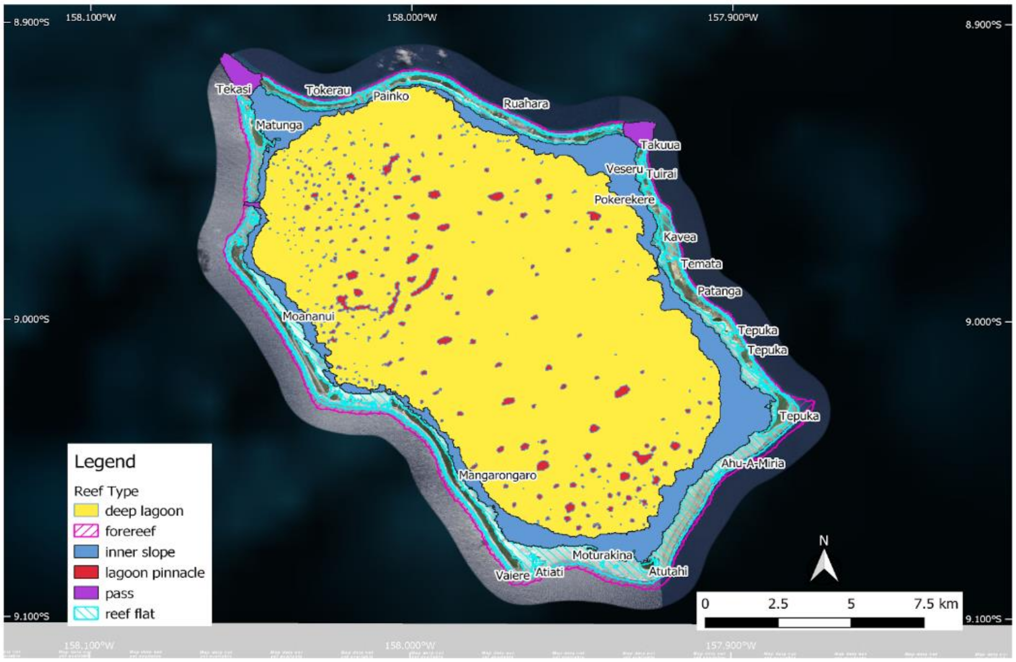

60%
50%
40%
30%
20%
10%
0%
% of people
Male
Female
Survey
Census


90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of people
None
Secondary/High School
Tertiary
Survey
Census

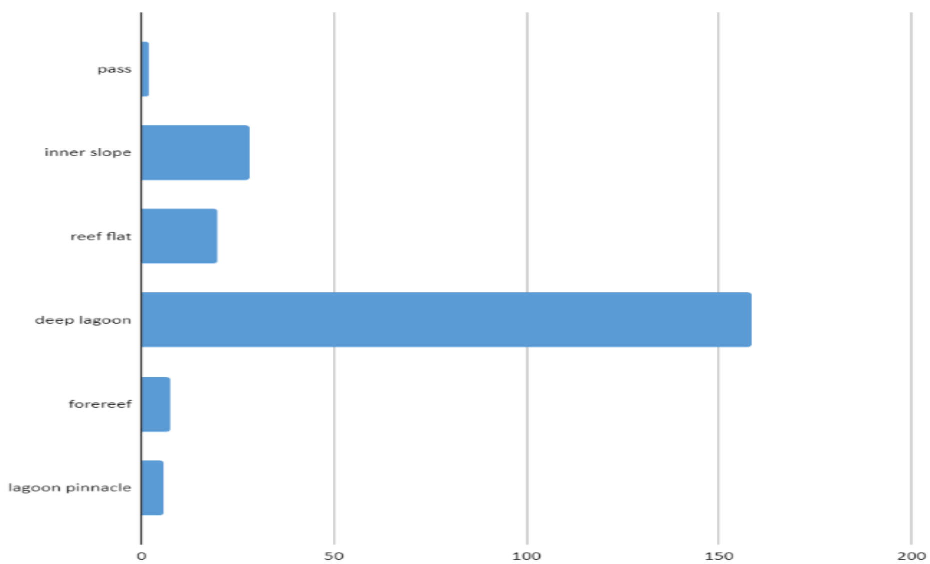

70%
60%
50%
40%
30%
20%
10%
0%
% of people
Less than $500
$500 - $3,000
$3,000 - $6,000
$6,000 - $10,000
Over $10,000
Survey
Census

15 Appendix V: Coastal protection

Penrhyn
Map



Reef Type Area

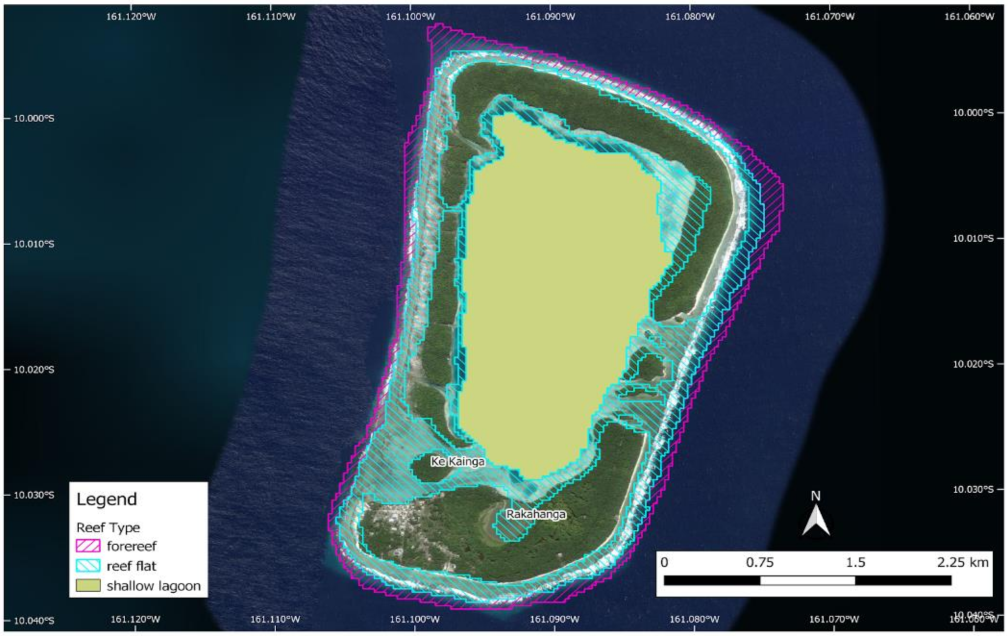


Coastal protection index

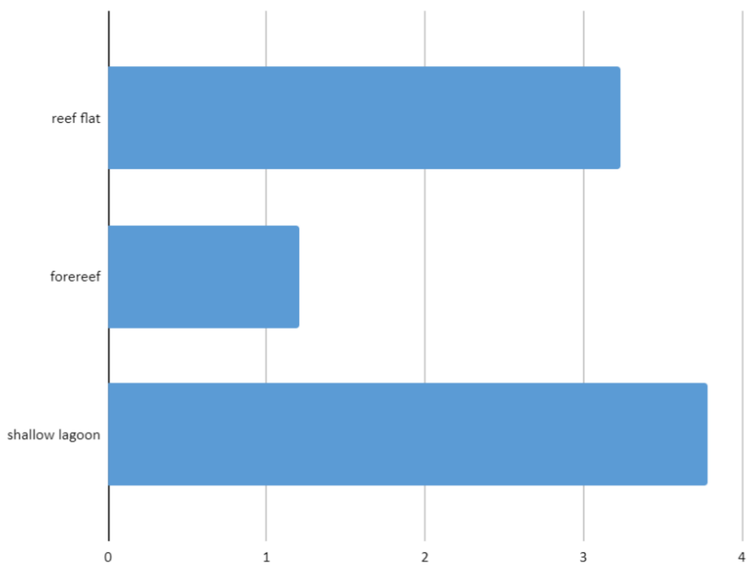
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
91	2x inhabited islands: Pokerekere & Moananui	Both villages Omaka (on Moananui isl.) and Te Tautua (on Pokerekere isl.) are located on the inner/lagoon side of the islands. Given the steep drop at the edge of the reef flats, forereef and lack of reef area may result in coastal flooding and damage to infrastructure during severe storm surges. In addition, both villages may take severe damage if severe storm surges were to occur from the inner lagoon	Potential infrastructure damage include: roads, buildings and jetties

Rakahanga

Map



Reef type area

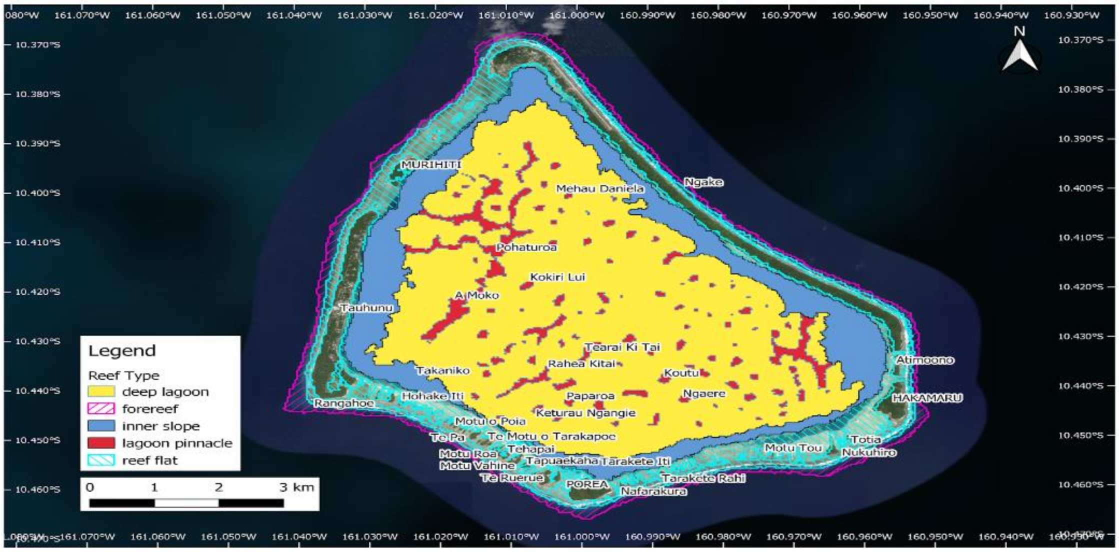


Coastal protection index

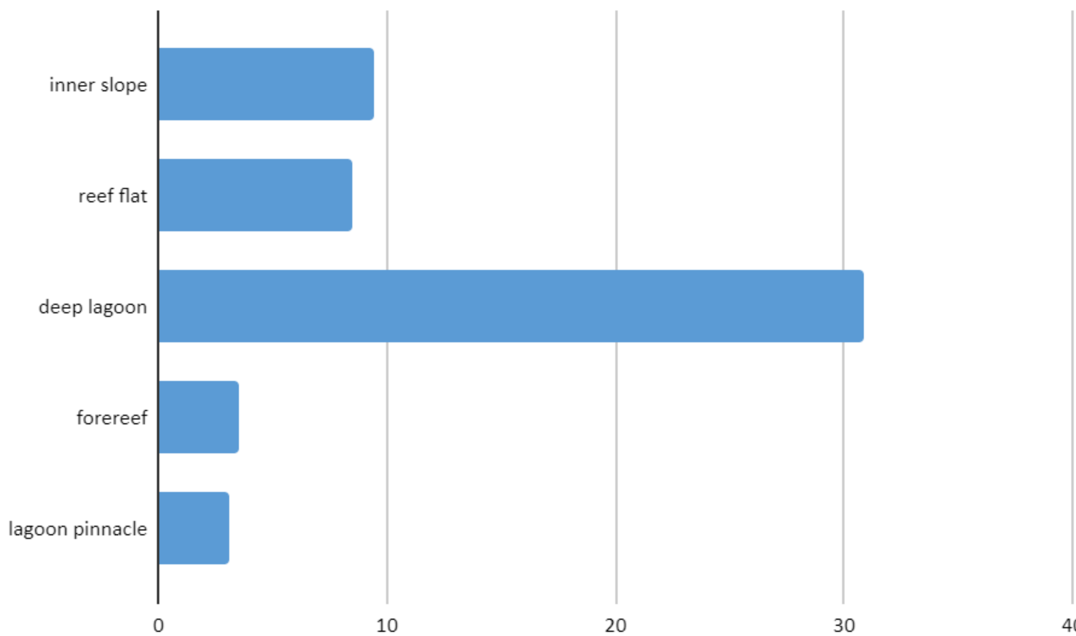
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
9	1 x inhabited island, Rakahanga	Nivano Village is sheltered by both reef flats & forereef. It is also protected by vegetation as well as an island (Te Kainga) just of the village.	Unlikely due to geographical location, surrounding vegetation and reefs.

Manihiki

Map



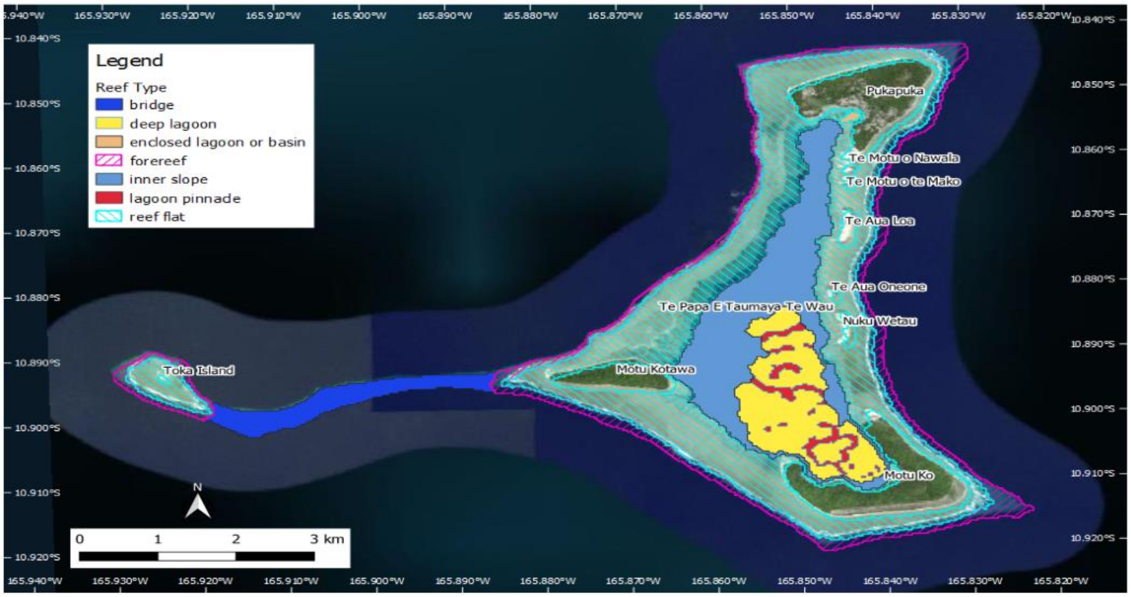
Reef type area



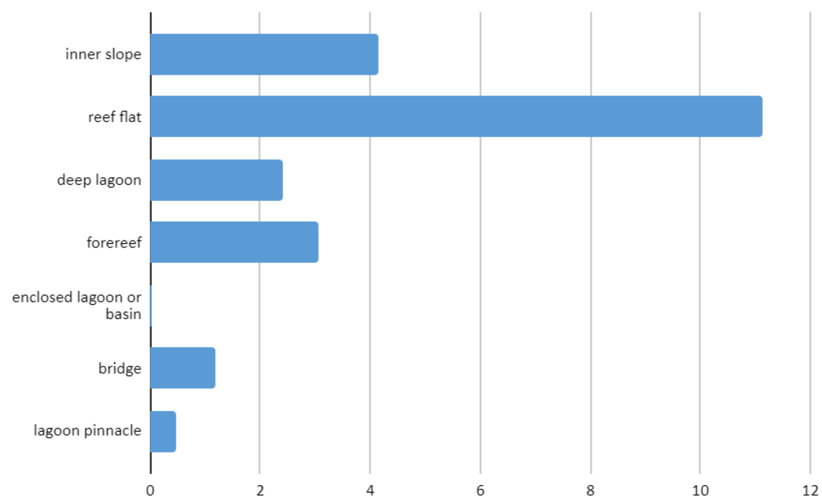
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
93	2x Tauhunu isl. & Ngake isl.	Both villages Tauhunu (on Tauhunu isl.) and Tukao (on Ngake isl.) are located on the inner/lagoon side of the islands. Given the steep drop at the edge of the reef flats, forereef and lack of reef area may result in coastal flooding and damage to infrastructure during severe storm surges. In addition both villages may take severe damage if severe storm surges were to occur from the inner lagoon	Potential infrastructure damage include: roads, buildings and jetties

Pukapuka

Map



Reef type area

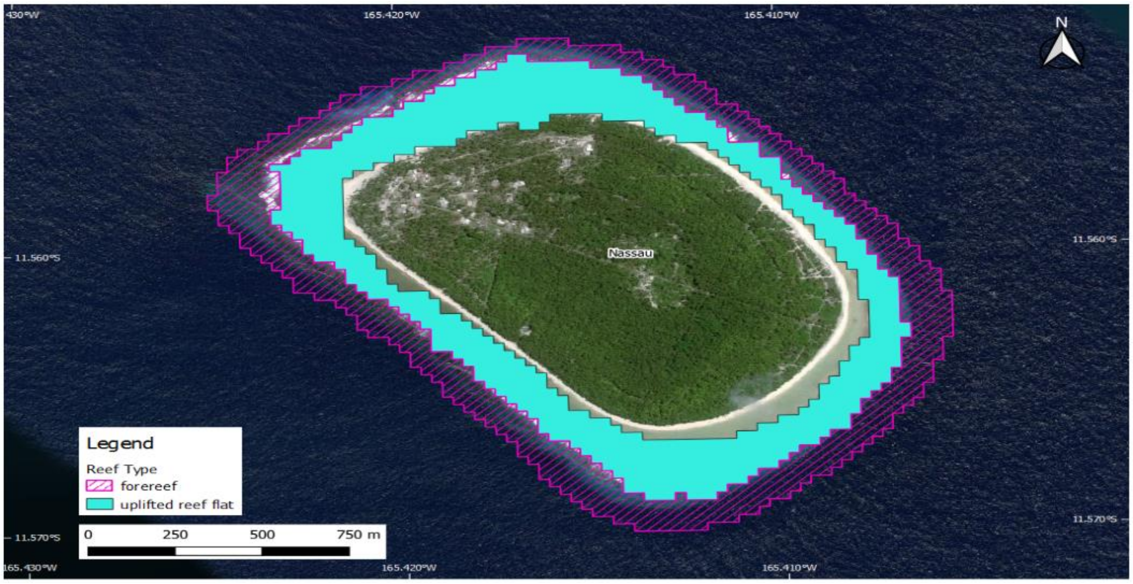


Coastal protection Index

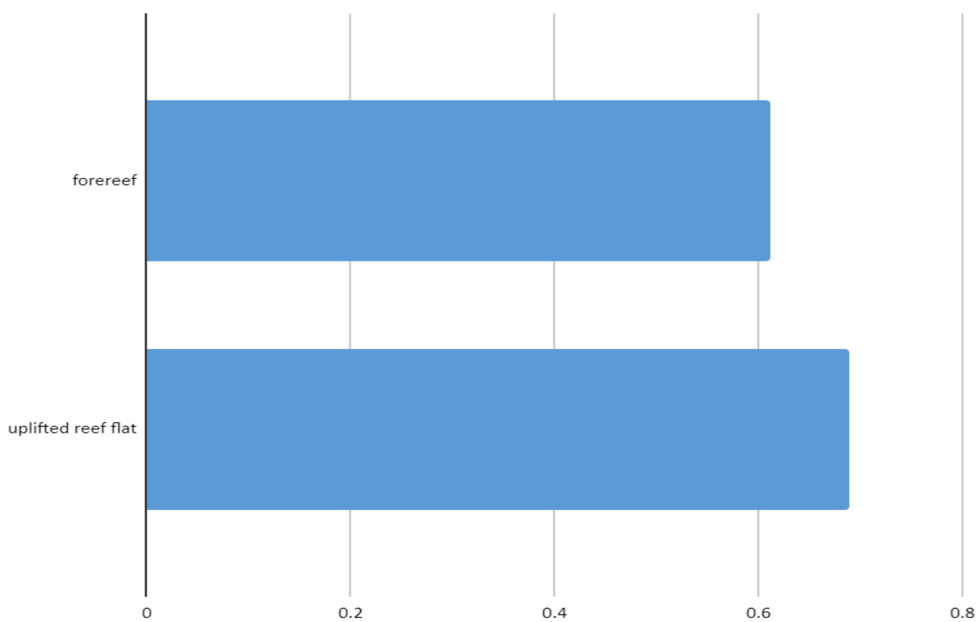
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
12	3x Pukapuka, Motu Kotawa & Motu Koe	All 3 villages are well sheltered in terms of geographical location, vegetation cover & surrounding reef area. Coastal damage may occur only during severe weather conditions.	infrastructure damage may occur only during severe weather conditions. Potential infrastructure damage include: roads, buildings and jetties

Nassau

Map



Reef type area

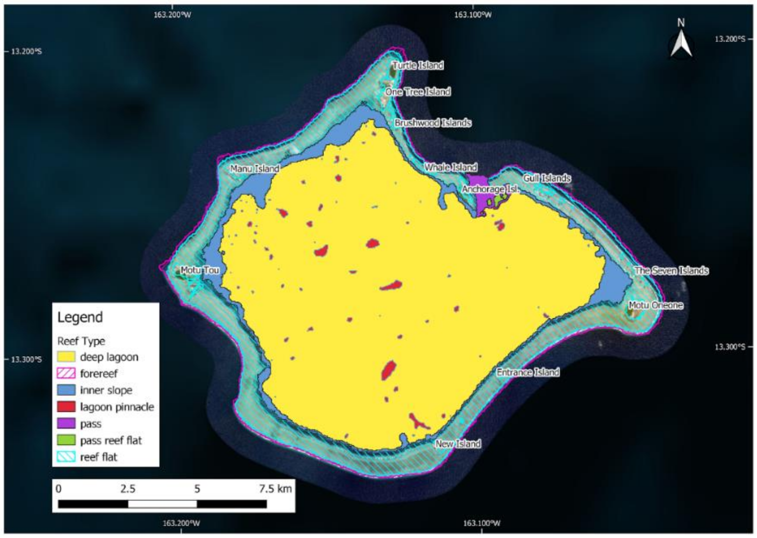


Coastal protection Index

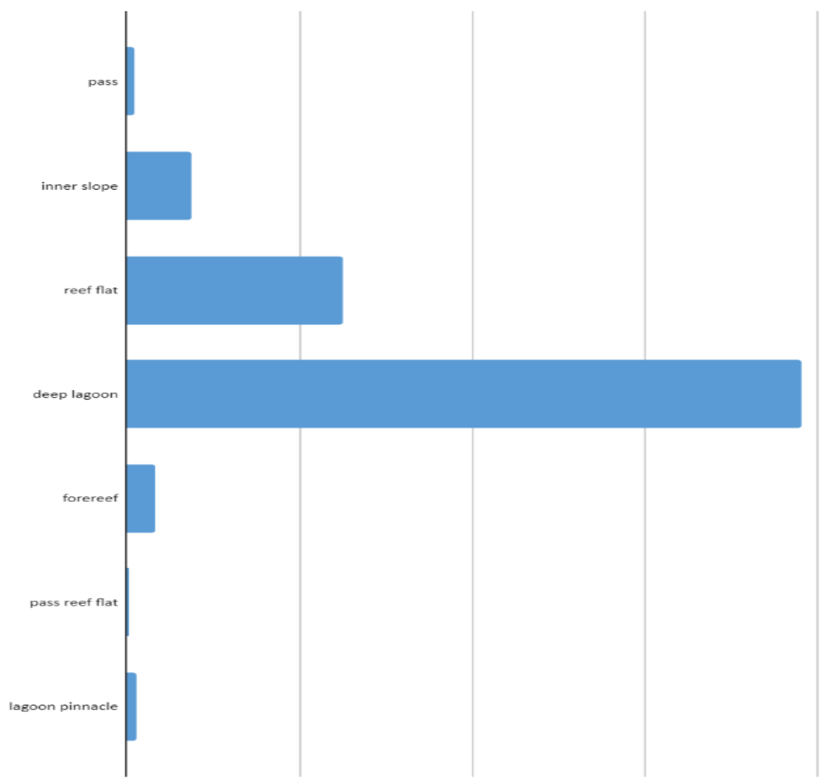
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	1 x Nassau isl.	Kikau village has an approximate distance of 150m from its beach to reef edge. Kikau village buildings are about 90-100m inland (from the beach). It is well sheltered by uplifted reef flats and reef edge.	Damage would mainly be caused by falling debris from surrounding vegetation (during strong winds or storm surges).

Suwarrow

Map



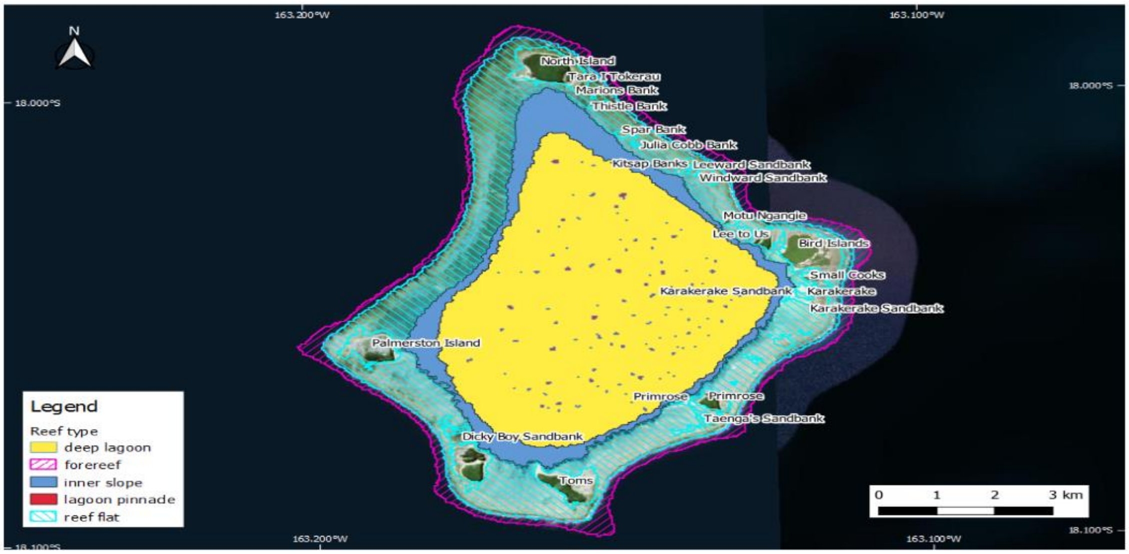
Reef type area



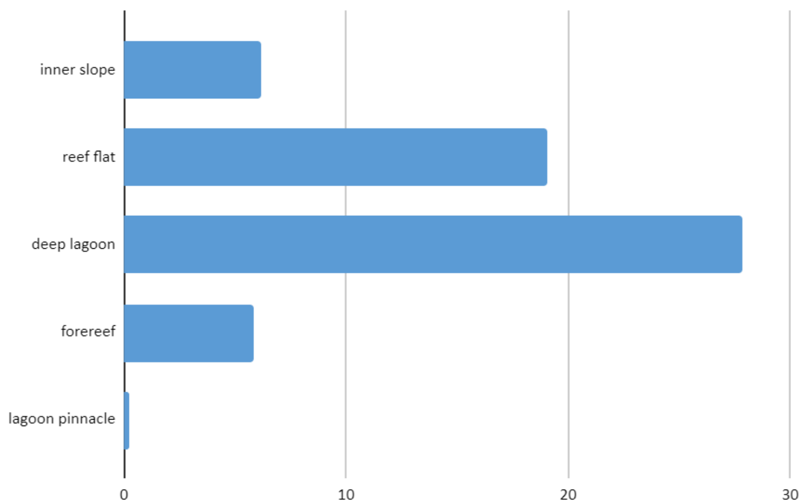
Coastal protection Index

Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
42	0	Given its remote location and uninhabited islands Suwarrows main vulnerability would be the geographical makeup of its little islands. Most islands have very little to-no vegetation. Given its seabird nesting grounds, strong storm surges or gusts could result in coastal erosion and damage to vegetation (affecting nesting grounds)	Not applicable

Palmerston
Map



Reef type area

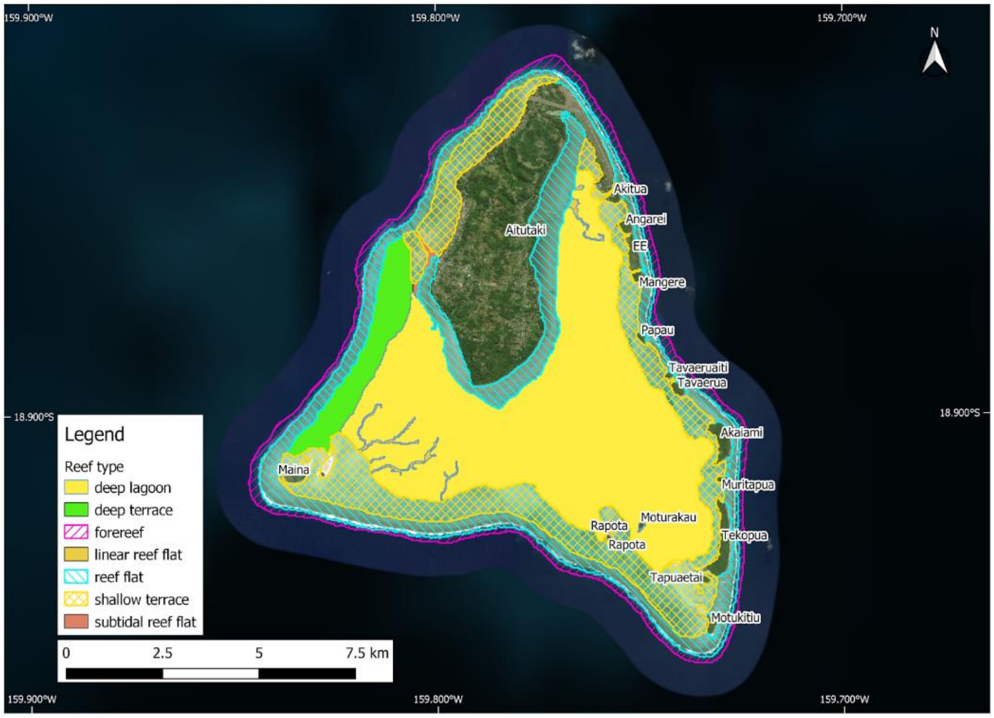


Coastal protection Index

Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
32	1 x Palmerston Isl.	Settlements are spread across the island. Lush vegetation (palms and coconut) provides good shelter from the weather. The reef area and lush vegetation indicates that the island is well protected.	Damage would mainly be caused by falling debris from surrounding vegetation (during strong winds or storm surges).

Aitutaki

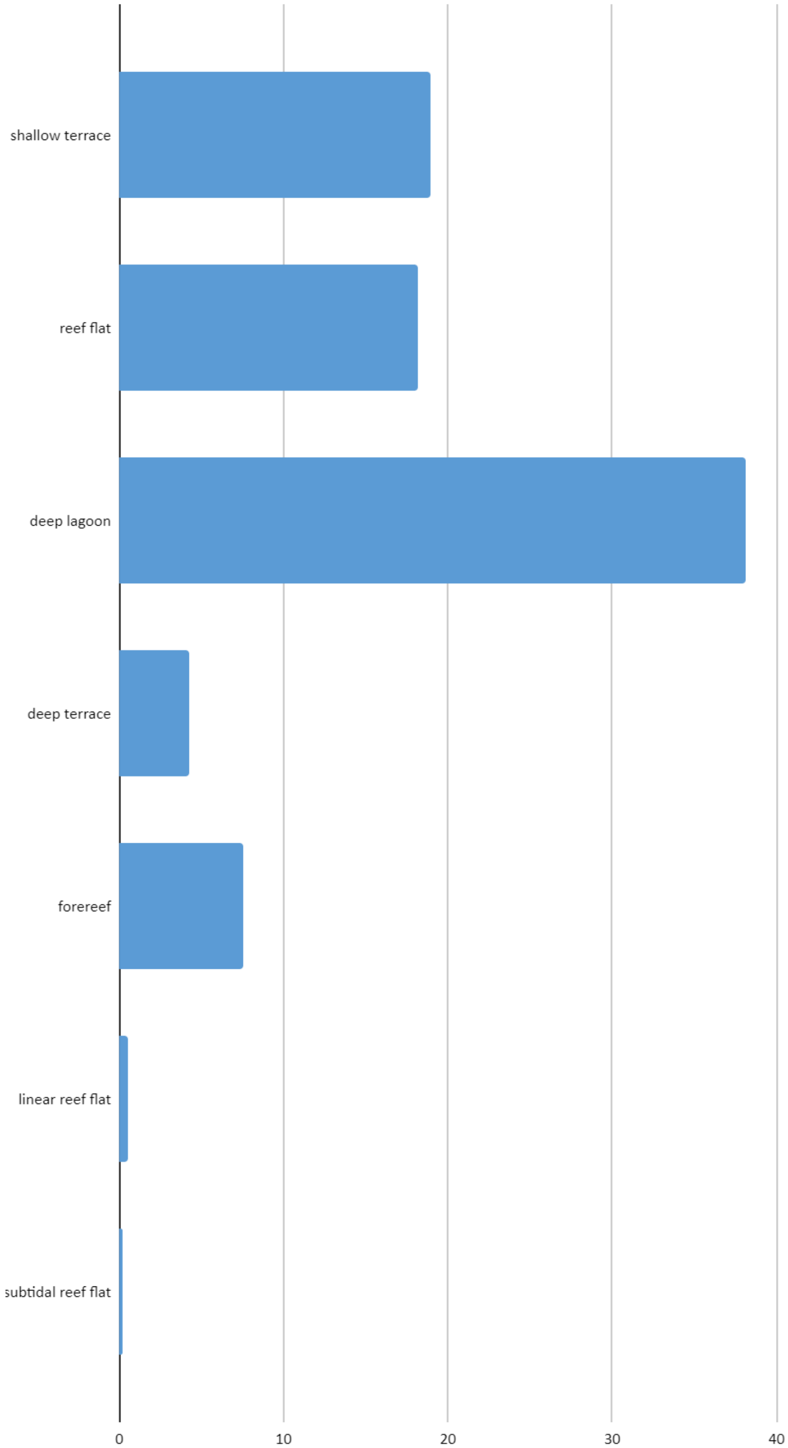
Map



Coastal protection Index

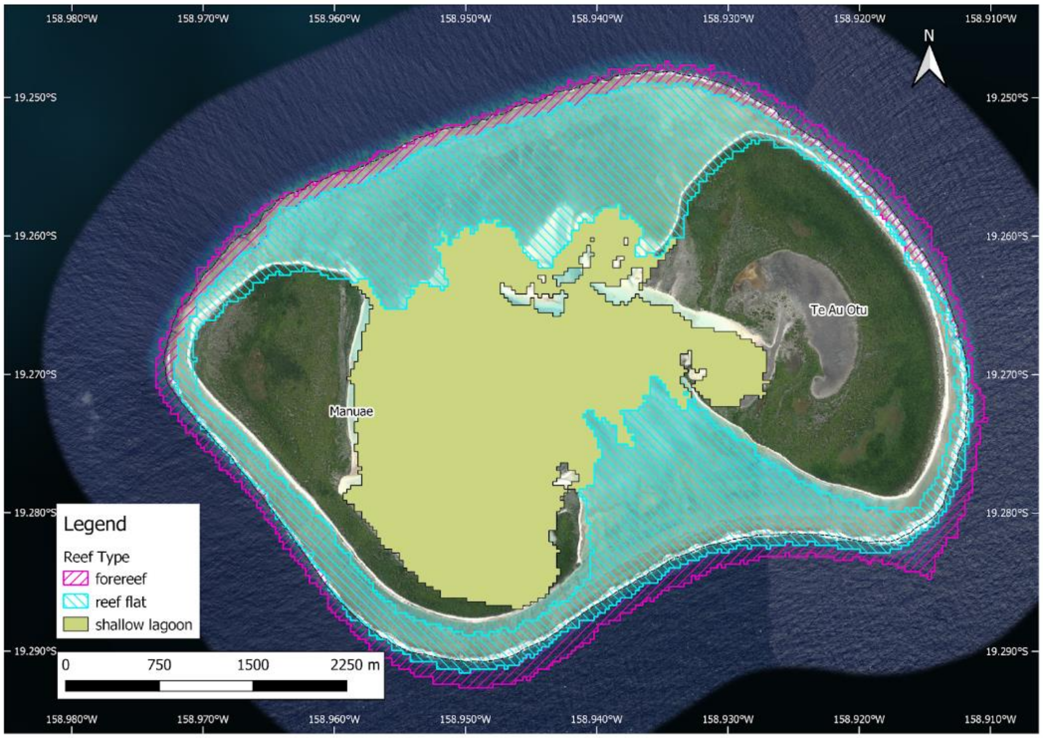
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
27	6	The biggest population is situated on the main island of Aitutaki with two major villages (Amuri & Arutanga). The main island has elevation, but a substantial amount of human settlement is focused around the coastal areas. There is also a significant amount of tourism, given the amount of facilities (guest houses, rentals, villa's.etc) that support the industry. Even with high reef area and a protected lagoon, there is potential for major damage during severe weather conditions.	Coastal communities within Amuri & Arutanga have high risks of infrastructure damage during severe weather events (especially communities located near the ocean-side on the western parts of Aitutaki. Loss would include, roads, buildings, businesses and potentially the airport to the north on Ootu peninsula.

Reef type area



Manuae & Te Au Otu

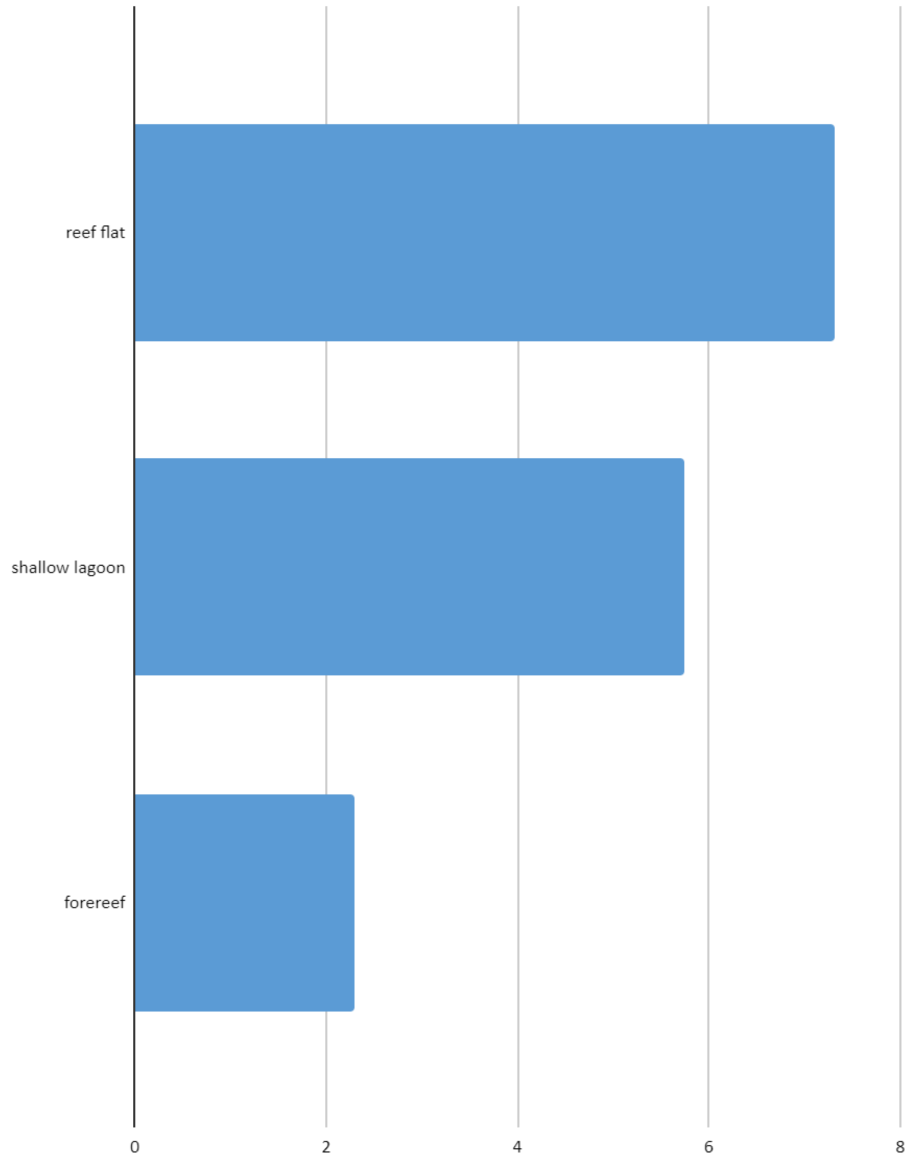
Map



Coastal protection Index

Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
3	0	Uninhabited islands surrounded by reef flats, forereef and shallow lagoons. Both islands have good vegetation cover as well as high reef areas. Coastal erosion (sand shift) is visible via satellite imagery. Vegetation loss is possible as a result of severe weather conditions.	Not applicable

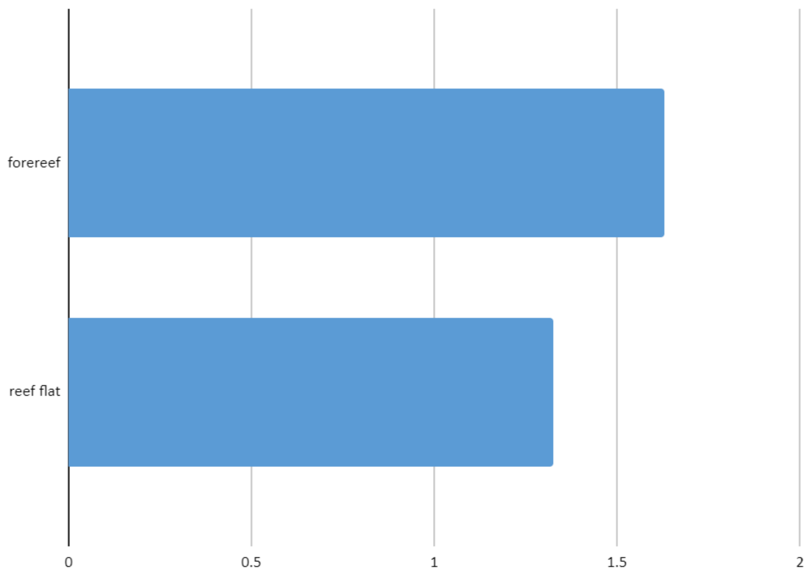
Reef type area



Takutea

Map

Reef type area

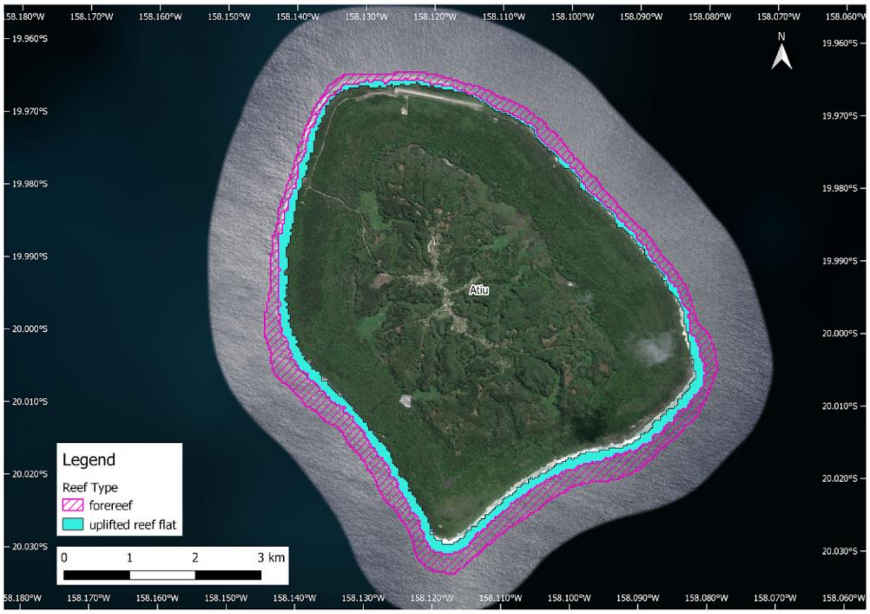


Coastal Protection Index

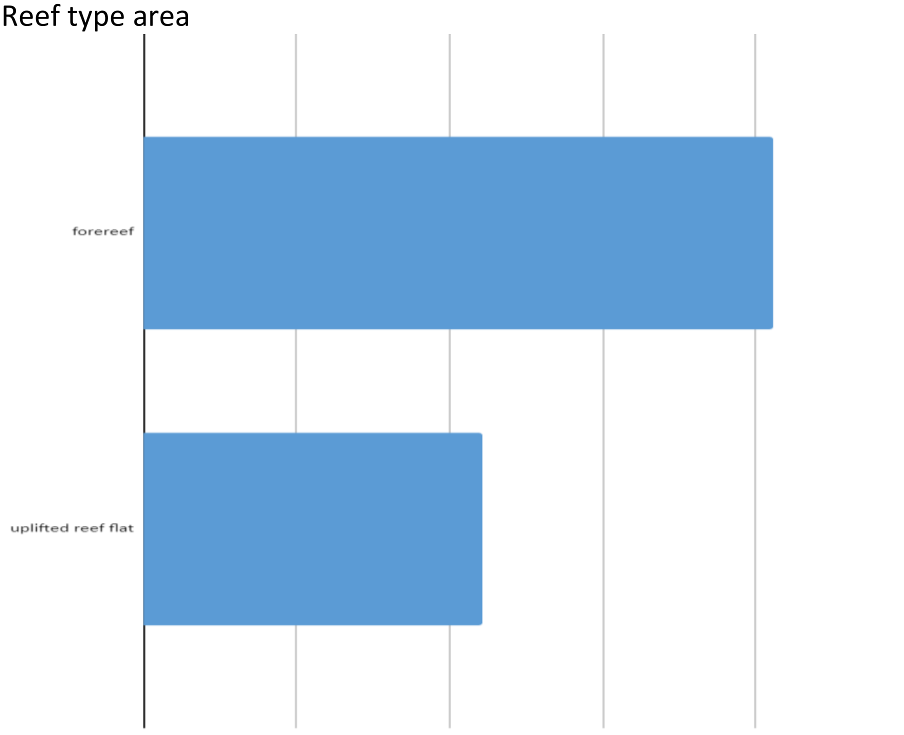
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	0	Uninhabited island surrounded by reef flats, forereef and shallow lagoons. Island has good vegetation cover as well as high reef areas. Coastal erosion (sand shift) is visible via satellite imagery. Vegetation loss is possible as a result of severe weather conditions.	Not applicable

Atiu

Map



Reef type area

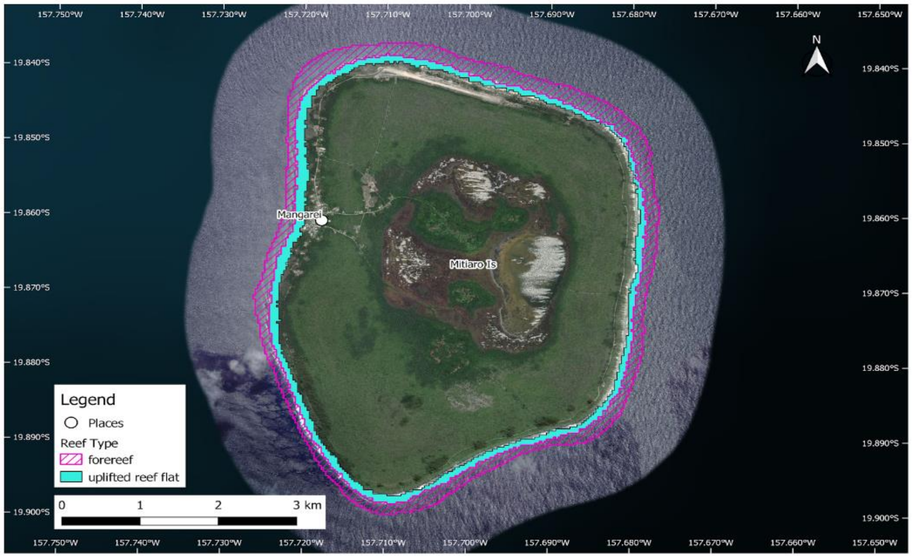


Coastal Protection Index

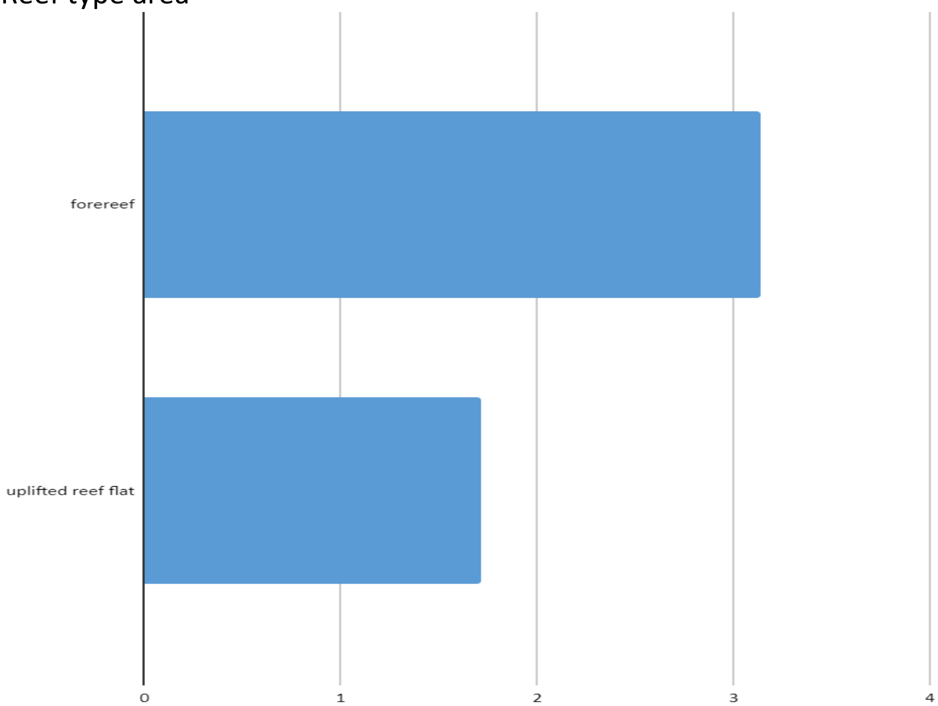
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast.	The most notable infrastructure is the airstrip due to its proximity to the beach. Other damages would include roads and jetty's.

Mitiaro

Map



Reef type area

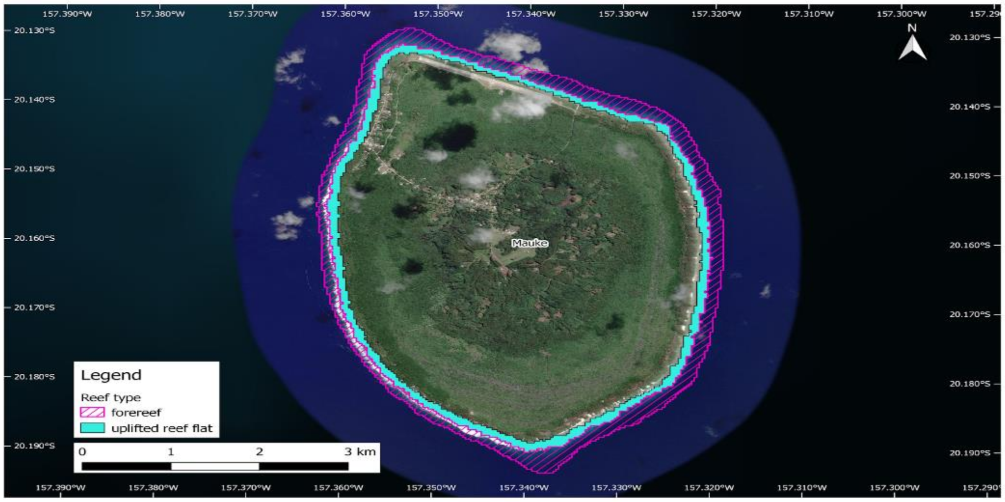


Coastal Protection Index

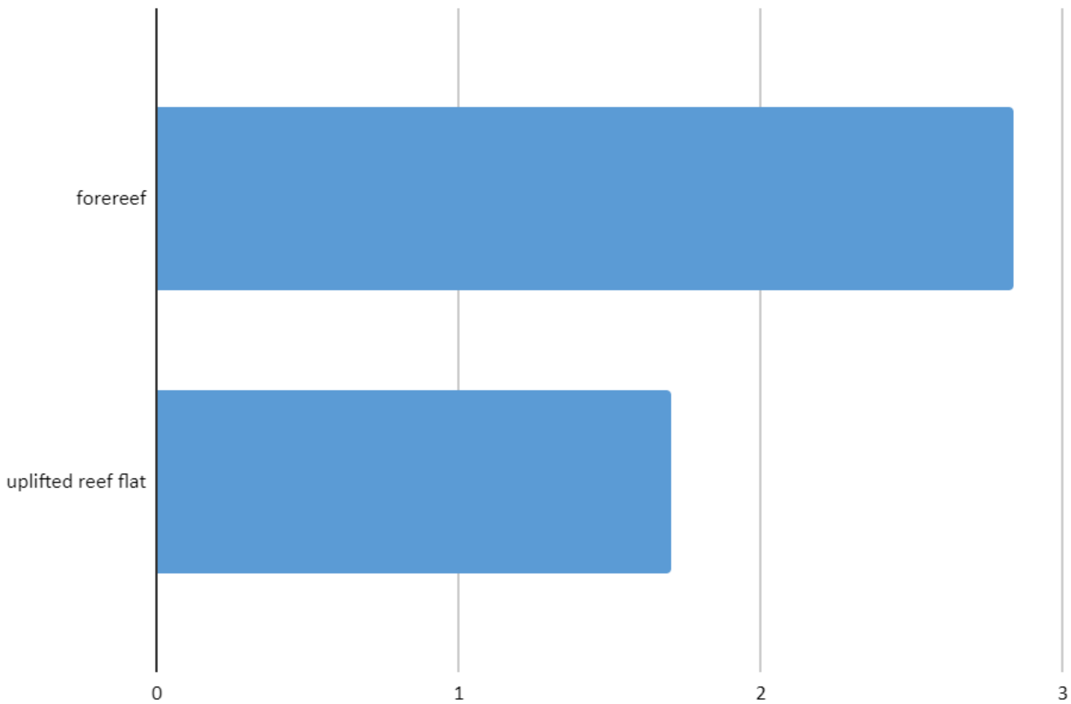
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation. Mangarei (village) would be the highest at risk of coastal damages given its proximity to shore (less than 100m).	Infrastructure damage includes buildings and roads/utilities.

Mauke

Map



Reef type area

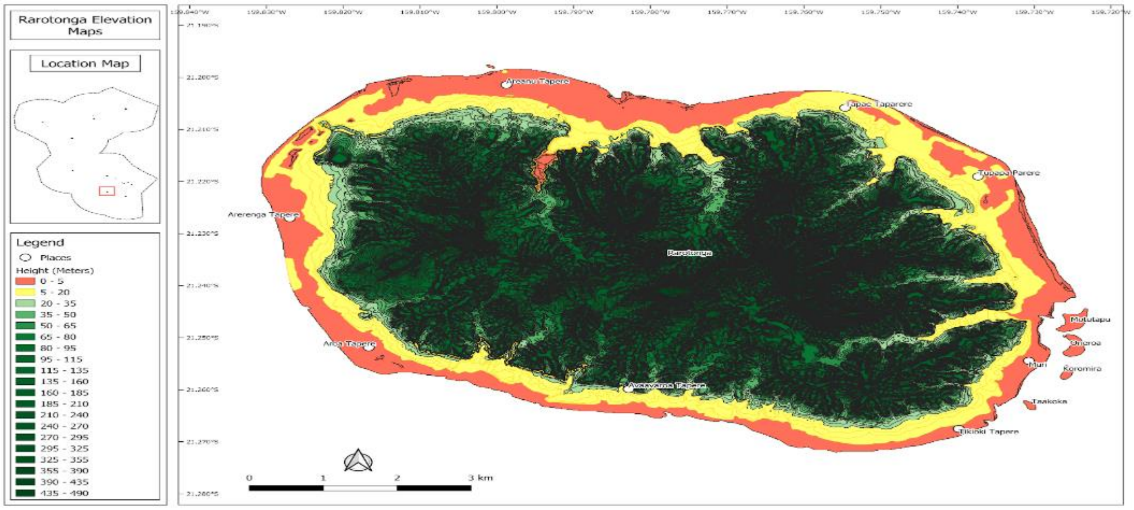


Coastal Protection Index

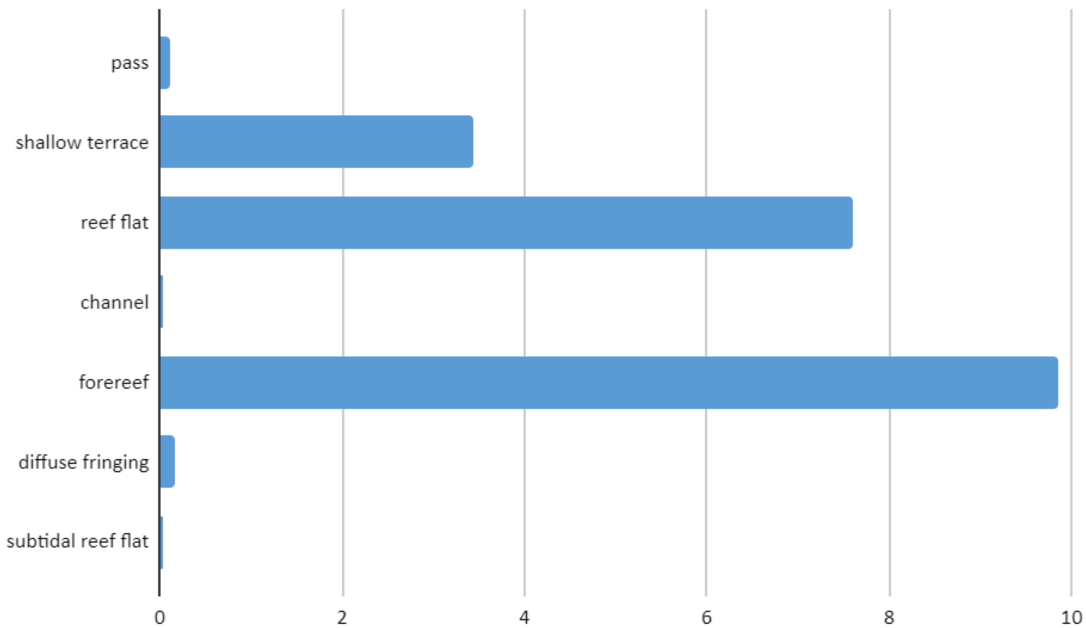
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast. Kimiangatau (village) would be the highest at risk of coastal damages given its proximity to shore (less than 100m).	Infrastructure damage includes buildings and roads/utilities.

Rarotonga

Map



Reef type area

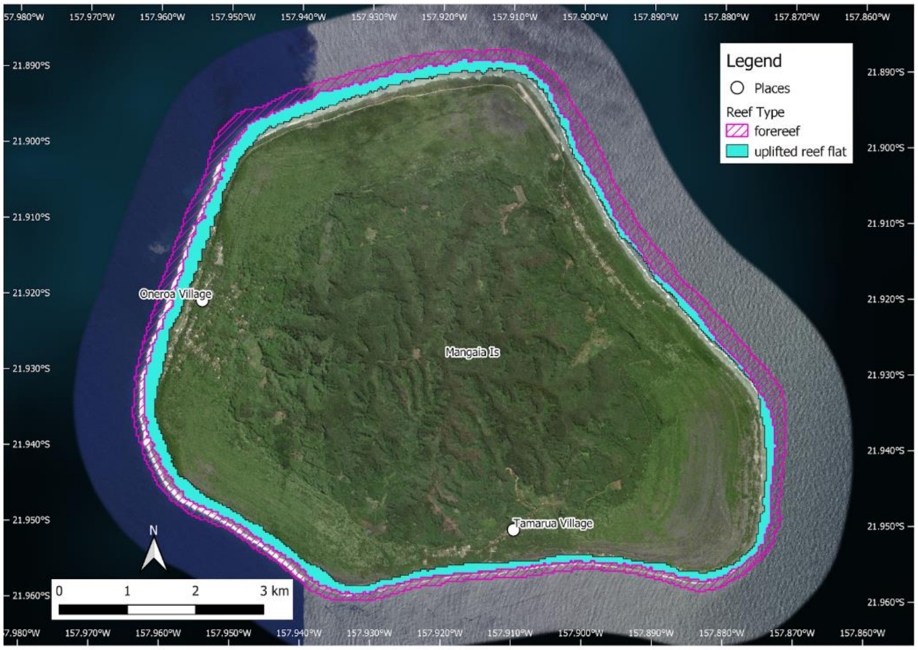


Coastal Protection Index

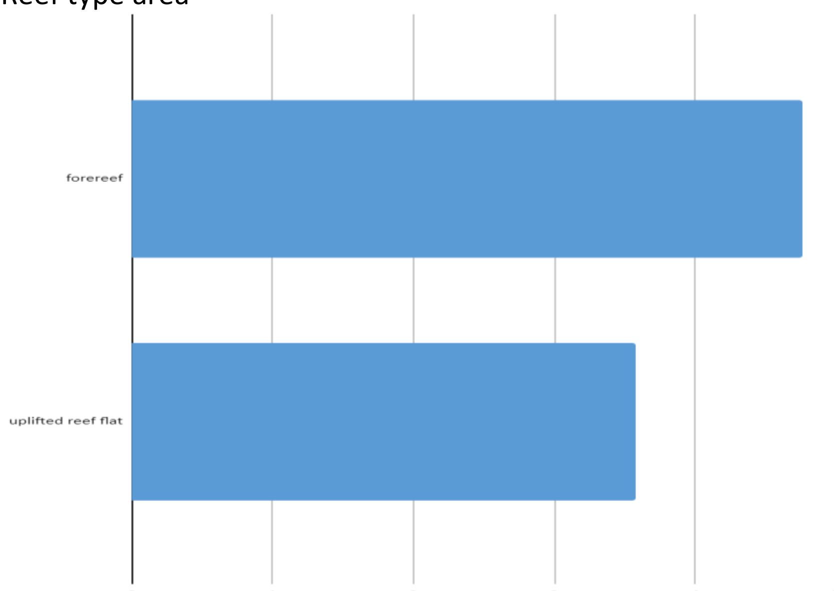
Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
5	1	Rarotonga has the highest risk in terms of population and development when it comes to natural disasters. Given its dense settlements to low lying areas, both infrastructure and livelihoods would be affected in the case of a natural disaster. The elevation map highlights areas that are prone to coastal flooding in terms of height above sea-level.	Utilities, buildings, roads, ports, jetties etc.

Mangaia

Map



Reef type area



Coastal Protection Index

Total # of Islands (parts in GIS)	# of Inhabited Islands (According to Satellite Image)	Vulnerability Assessment (Summary)	Vulnerability Assessment (Infrastructure)
1	1	Low reef area coverage of uplifted reef flats and forereef. Clear signs of coastal erosion due to exposed rocky shores. Lush vegetation and safe geographical location of settlements away from the coast. Oneroa (village) would be the highest at risk of coastal damages given its proximity to shore (less than 100m).	Infrastructure damage includes buildings and roads/utilities from the Oneroa village and airstrip.

16 Appendix VI: Choice experiment valuation

Discrete choice experiment

To obtain quantitative measures of Cook Islanders' preferences for environmental conservation, we make use of the discrete choice experiment (DCE) method. This stated preference method uses a public survey to elicit the preferences or values of respondents for specified changes in a good or service (Hensher et al., 2005). In the fields of market research and economics the DCE method is widely used to obtain information on public preferences that are otherwise not observable in consumer behaviour (Johnston et al., 2017).

The main theoretical underpinnings of the DCE method are derived from the characteristics theory of value (Lancaster, 1966) and random utility theory (McFadden, 1974). The characteristics theory of value posits that consumer behaviour is driven by the constituent characteristics of a good rather than the good itself. Random utility theory posits that measured consumer utilities (welfare) should be treated as random variables to reflect that the observer lacks information on each good's characteristics and alternatives, as well as incomplete information on consumers (Manski, 1977; Caussade et al., 2005). The DCE method attempts to measure the preferences (random utilities) people have for environmental qualities (the characteristics of the good/service they consume).

In practical terms, a DCE involves asking survey respondents to make repeated choices between alternative multi-attribute descriptions of a good or service. It is possible to estimate their relative values of these goods and services by observing the trade-offs that are made between attributes (Hanley et al. 2001). By including one attribute that represents a monetary payment on the part of the respondent it is also possible to estimate the willingness to pay (WTP) for changes in the other attributes (Pearce et al. 2002). In the present study, respondents were asked to choose between alternative options for conservation of the marine environment that would be funded through monthly donations to an administered fund dedicated to marine conservation in the Cook Islands. By analysing the trade-offs that respondents made between conservation measures and the payment, we were able to quantify their willingness to pay for each measure.

Selection of attributes

In the present study, the selected attributes were:

- Fish and shellfish abundance. The abundance of fish and shellfish that can be caught
- Water quality for recreation. The quality of coastal water that can be used for leisure/recreation
- Marine biodiversity. The diversity of native and migratory marine animal species
- Cost per month. The money amount in NZD that the respondent would be willing to pay each month through a donation to an administered fund dedicated to marine conservation in the Cook Islands.

The attributes and their levels are provided in Table 1.

Table 1. Choice experiment attributes and levels.

Level	Reef fish abundance	Water quality for recreation	Marine biodiversity	Cost per month (NZD)
1	low	poor	low	0
2	moderate	moderate	moderate	2
3	high	high	high	5
4				10
5				15

Experimental design

The experimental design of a DCE defines the attributes used to describe alternative options, the levels that each attribute can take, the combination of attribute levels in each option, the combination of options in each choice card, and the number of separate choices respondents are asked to make.

The experimental design in the present study includes the four selected attributes above (i.e., three environmental characteristics and one payment vehicle). In our experimental design, all three environmental attributes are defined by three levels; and the payment is defined by five levels. Payment levels were established by considering amounts that would be considered reasonable by Cook Islanders, and differences between levels that are sufficiently large for respondents to distinguish between them.

Since the representation of all possible combinations of attribute levels across options would generate an infeasible number of choices, a fractional factorial design was used to limit the number of choices and ensure orthogonality (statistical independence of attributes and levels). The statistical design was generated using Sawtooth software[15] to optimize the combinations of attribute levels within and across choice cards to enable the statistical estimation of the influence of each attribute level on respondent choice (i.e. respondent preferences). We manually checked and modified the statistical design to avoid the occurrence of dominant options, i.e. the case that one option was superior to the other across all attributes. We note that a common alternative to using orthogonal designs are so-called efficient designs that are able to produce more reliable parameter estimates with an equal or smaller sample size (Rose et al., 2009). The experimental design defines 60 choice cards. Each respondent was asked to select their preferred option out of three options on a choice card and asked to repeat the choice process in 6 randomly selected cards. Of the three options on each choice card, one option is held constant across all cards to represent a 'no additional protection' opt-out, for which the four environmental attributes are at their lowest level and no additional payment is made.

[15] Orem, Utah, United States (2016) https://www.sawtoothsoftware.com/.

Choice representation

The attribute levels defining each option are represented on choice cards using simple images to provide respondents with a visual support for understanding the differences between options. The representation of attributes and choice cards were tested for comprehension during the pilot survey and found to effectively communicate the provision of each service. An example choice card is represented in Figure 5.

Figure 5. Example choice card

Modelling approach

The data from the choice experiment were analysed using a standard logit (McFadden 1974) and a mixed logit (MIXL) model (Revelt and Train 1998). The MIXL model is a generalization of the standard logit model in that the MIXL model accounts for the possibility that the preferences determining choices differ between individuals. MIXL models generally fit the data better than do standard logit models.

We assumed that the estimated random parameters were normally distributed except for the parameter for the variable 'Payment', which we assumed to have a negative lognormal distribution. All variables indicating effects of conservation actions were dummy-coded. We normalized the alternative-specific constants (which capture unobserved biases) on the opt-out option.

The software we used to estimate the choice model was the Apollo package version 0.2.1 (Hess and Palma 2019) for use with R version 4.0.2 (R Core Team 2020). To estimate WTP and the confidence intervals, we used procedures specified in Train (2009) and the parametric bootstrap proposed by Krinsky and Robb (1986).

Results

The estimated standard logit and MIXL choice models are given in Tables 1 and 2. The MIXL model provides a better fit for the data, indicated by the smaller Log-Likelihood score and the higher adjusted ρ^2 (McFadden 1974). The MIXL model's higher explanatory power offsets its higher complexity, which can be seen by a reduced value of the Bayesian Information Criterion (BIC).

In the MIXL model, the means of the estimated coefficients are all significant at the 1% level and have the expected signs. The variation in preferences for moderate environmental increases are not significant, however. This suggests that the respondents had similar preferences for moderate improvements over low environmental quality, whereas their preferences for raising environmental conditions to high levels were more diverse.

The ASCs for options 1 and 2 are both positive, indicating respondents were more likely to select a conservation option than the business-as-usual option. The estimated ASC coefficients are of similar size, indicating the absence of unobserved biases in respondents' choices.

The estimated coefficient for payments to finance conservation efforts is comparatively large and negative due to its assumed (negative lognormal) distribution. The estimated model suggests that respondents' choices were quite insensitive to the Payment variable.

The distribution of WTP is calculated using the estimated coefficients of the choice models, shown in Table 3. The mean of the WTP is significantly higher than the median, reflecting the logarithmic distribution with small numbers of exceedingly high WTP values. Using medians negates the influence of such unlikely WTP values.

Table 1. Multinomial logit regression model

	Estimate	s.e.[a]	Significance[b]
Option 1	1.126	0.370	***
Option 2	0.897	0.396	**
Fish abundance – Moderate over Low	0.741	0.161	***
Fish abundance – High over Low	0.597	0.165	***
Water quality for recreation – Moderate over Low	0.912	0.159	***
Water quality for recreation – High over Low	0.852	0.175	***
Marine biodiversity – Moderate over Low	0.746	0.153	***
Marine biodiversity – High over Low	0.991	0.183	***
Payment	-0.024	0.010	**
N	570		
Log-Likelihood	-420.92		
Adj. ρ^2	0.314		
BIC	898.95		

[a] robust standard errors

[b] *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2. Mixed logit regression model

	Estimate	s.e.[a]	Significance[b]
Option 1	1.637	0.535	***
Option 2	1.274	0.551	**
Fish abundance – Moderate over Low			
Mean	0.974	0.212	***
s.d.	0.471	0.427	
Fish abundance – High over Low			
mean	0.797	0.216	***
s.d.	-0.668	0.388	*
Water quality for recreation – Moderate over Low			
mean	1.240	0.218	***
s.d.	0.078	0.375	
Water quality for recreation – High over Low			
mean	1.280	0.254	***
s.d.	0.660	0.264	***
Marine biodiversity – Moderate over Low			
mean	1.048	0.195	***
s.d.	0.274	0.586	
Marine biodiversity for recreation – High over Low			
mean	1.426	0.241	***
s.d.	-0.739	0.346	**
Payment			
mean	-4.269	0.592	***
s.d.	-2.148	0.332	***
N	570		
Log-Likelihood	-391.88		
Adj. ρ^2	0.349		
BIC	885.29		

[a] robust standard errors
[b] *** p < 0.01, ** p < 0.05, * p < 0.1

Table 3. Distribution of willingness to pay

	Willingness to Pay (NZD/household/month)		
	Median	Median C.I. low	Median C.I. high
Fish abundance – Moderate over Low	68	16	166
Fish abundance – High over Low	46	9	120
Water quality for recreation – Moderate over Low	100	29	232
Water quality for recreation – High over Low	87	27	197

Marine biodiversity – Moderate over Low	75	19	181
Marine biodiversity – High over Low	100	29	234