NATIONAL MARINE ECOSYSTEM SERVICE VALUATION

VANUATU

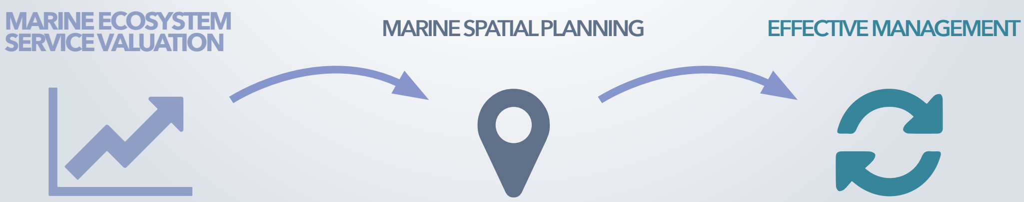
MACBIO

MARINE ECOSYSTEM SERVICE VALUATION

The living resources of the Pacific Ocean are part of the region's rich natural capital. Marine and coastal ecosystems provide benefits for all people in and beyond the region. These benefits are called ecosystem services and include a broad range of values linking the environment with development and human well-being.

Yet, the natural capital of the ocean often remains invisible. Truly recognizing the value of such resources can help to highlight their importance and prevent their unnecessary loss. The MACBIO project provides technical support to the governments of Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu in identifying and highlighting the values of marine and coastal resources and their ecosystem services. Once values are more visible, governments and stakeholders can plan and manage resources more sustainably, and maintain economic and social benefits of marine and coastal biodiversity in the medium and long term.

The MACBIO Project has undertaken economic assessments of Vanuatu's marine and coastal ecosystem services, and supports the integration of results into national policies and development planning. For a copy of all report and communication material please visit **www.macbio.pacific.info**.



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VANUATU

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Marine and Coastal Biodiversity Management in Pacific Island Countries

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On behalf of:
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Marine and Coastal Biodiversity Management in Pacific Island Countries

VANUATU

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FIGURES AND TABLES

ACRONYMS

ADB	Asian Development Bank
AFD	Agence Française de Développement
AIA	Analysis of Advertising Images
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CRC	Cobalt-rich crusts
CRISP	Coral Reefs in the Pacific
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSM	Deep sea minerals
EEZ	Exclusive Economic Zone
EU	European Union
EUA	European Union Allowances
FAD	Fish Aggregating Devices
FFA	Pacific Islands Forum Fisheries Agency
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GIZ	German Agency for International Cooperation
HCFC	Chlorofluorodimethane, a synthetic greenhouse gas
HIES	Household Income and Expenditure Survey
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
MACBIO	Marine and Coastal Biodiversity Management in Pacific Island Countries
MESCAL	Mangrove Ecosystems for Climate Change Adaptation and Livelihoods project
MPA	Marine protected areas
MSWG	Marine Sector Working Group
MSY	Maximum sustainable yield
NGO	Non-government organisation
PIFS	Pacific Island Forum Secretariat
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RESCCUE	Restoration of Ecosystems Services against Climate Change Unfavourable Effects
RSE	Relative standard errors
SCC	Social cost of carbon
SMS	Seafloor massive sulphides
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
TAC	Total allowable catch
TEEB	The Economics of Ecosystems and Biodiversity
UNCBD	United Nations Convention on Biological Diversity
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard
VER	Verified Emission Reductions
VNSO	Vanuatu National Statistics Office
VTO	Vanuatu Tourism Office
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WCPOC	Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
WTP	Willingness-to-pay

EXECUTIVE SUMMARY

This study aimed to estimate the *economic value* of seven marine and coastal *ecosystem services*[1] in Vanuatu. It is part of the MACBIO (Marine and Coastal Biodiversity Management in Pacific Island Countries) project, which aims to improve the management of marine and coastal biodiversity in Pacific Island countries.

Marine and coastal ecosystems provide important benefits for society and contribute to the livelihoods, food security and safety of millions of people around the world. These benefits (called *ecosystem services*) are often not visible in national accounts or in business operations, and their value is usually only perceived when we lose them. Assigning monetary values to ecosystem services is a powerful tool which makes these benefits visible and may contribute to improving the wise use and management of the ecosystems that provide them.

This study used a literature review, expert opinion and results from existing surveys to estimate an *economic value* for each of the seven ecosystem services before aggregating the values at the national scale. The marine and coastal ecosystems valued include open oceans, coral reefs, mangroves, seagrass, other soft seabed communities and seamounts.

We found that the seven marine and coastal ecosystem services categories assessed in Vanuatu had a total estimated *economic value* of Vt 4,266 million (in 2013 Vatu; Table 1), or US$ 48 million (in 2013 US dollars; Table 2) per year. Reflecting the uncertainty of this estimate, the value is likely to be in the range Vt 3,325–5,718 million (US$ 37–64 million).

Uses of ecosystems can conflict with each other (e.g. mining of minerals and aggregate and marine tourism) but our valuation inherently addressed this conflict. For example, if mining has reduced the value of marine tourism, the lower value for tourism is reflected in our analysis. Any unsustainable use of ecosystem services (e.g. overfishing) may also lead to a lower value of these services in the future.

The sum of all the ecosystem service values provided in this report represents a minimum value of Vanuatu's marine resources because not all the ecosystem services were able to be valued.

TABLE 1 • Annual economic value of marine and coastal ecosystem services in Vanuatu (2013) (Vt)

Ecosystem service	Annual value-added (Vt million)	Minimum (Vt million)	Maximum (Vt million)
Subsistence fishery	**577.61**	**519.76**	**635.46**
Commercial fisheries (total)	**623.45**	**515.76**	**731.14**
Reef fish, deep slope fish, crabs and lobster	293.7	264.33	323.96
Trochus and similar	8.9	7.565	10.235
Bêche-de-mer	4.45	2.67	6.23
Aquarium trading	13.35	8.01	18.69
Offshore fishing	160.2	112.14	208.26
Game fishing	142.4	121.04	163.76
Minerals and aggregates	**15.13***	**15.13**	**15.13**
Tourism and recreation	**853.51**	**612.77**	**1,095.15**
Coastal protection	**1,634.75**	**1,226.06**	**2,043.44**
Carbon sequestration	**125.49**	**1.76**	**760.95**
Research, management and education	**434**	**434**	**434**
Total	**4,266.66**	**3,325.4**	**5,718.25**

*Gross value — costs could not be estimated.

1 Throughout this report, terms in italics are explained in the glossary (Appendix I).

TABLE 2 • Annual economic value of marine and coastal ecosystem services in Vanuatu (2013) (US$)

Ecosystem service	Annual value-added (US$ million)	Minimum (US$ million)	Maximum (US$ million)
Subsistence fishery	**6.49**	**5.84**	**7.14**
Commercial fisheries (total)	**7.01**	**5.80**	**8.22**
Reef fish, deep slope fish, crabs and lobster	3.3	2.97	3.64
Trochus and similar	0.1	0.085	0.115
Bêche-de-mer	0.05	0.03	0.07
Aquarium trading	0.15	0.09	0.21
Offshore fishing	1.8	1.26	2.34
Game fishing	1.6	1.36	1.84
Minerals and aggregates	**0.17***	**0.17**	**0.17**
Tourism and recreation	**9.59**	**6.89**	**12.31**
Coastal protection	**18.37**	**13.78**	**22.96**
Carbon sequestration	**1.41**	**0.02**	**8.55**
Research, management and education	**4.9**	**4.9**	**4.9**
Total	**47.94**	**37.4**	**64.25**

*Gross value — costs could not be estimated.

The most economically important ecosystem service valued is coastal protection provided by coral reefs, mangroves and seagrass, followed by tourism and recreation, fisheries and support to research, management and education.

Tens of thousands of people depend directly on one or more coastal and marine ecosystem services in Vanuatu. We identified the following groups that receive significant benefits:

- Fishers in the commercial artisanal fishery (> 5,200 households equivalent to approximately 10% of the households in Vanuatu)
- Local families for whom fishing on the reef and in the mangroves is a source of regular protein (15,500 households, approximately 30% of households in Vanuatu, equivalent to a population of > 74,000 individuals)
- Service providers and users of marine tourism (50 businesses, > 56,000 users per year, mainly foreigners)
- Real estate owners protected from coastal flooding (equivalent to 2,000–3,400 residences and 43,000–71,000 m^2 of hotel infrastructure)
- Tourism businesses that depend on the quality of water and beach formation (> 120 hotels, 1,100 jobs, > 70,000 tourists per year)
- The global community, which benefits from carbon sequestration and biodiversity.

For some specific ecosystem services (e.g. *bêche-de-mer* fishery, trochus fishery, the reef fishery close to Port Vila, illegal sand extraction), annual harvests are considered close to or above the sustainable level.

1. INTRODUCTION

1.1 MARINE AND COASTAL BIODIVERSITY MANAGEMENT IN PACIFIC ISLAND COUNTRIES (MACBIO)

Funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) for a period of five years through the International Climate Initiative (IKI), the Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project aims to strengthen the sustainable management of marine and coastal biodiversity by supporting economic ecosystem assessments, marine spatial planning and consultations in regard to marine protected areas (MPAs). The economic valuations of marine ecosystems will contribute to national development plans. The project also aims to assist governments to extend and/or redesign MPA networks using seascape-level planning. The project will, in addition, demonstrate effective approaches for site management, including payment for ecosystem services and other conservation finance tools. Tried and tested concepts and instruments will be shared with governments and stakeholders throughout the Pacific community and disseminated internationally.

MACBIO is being implemented in five Pacific Island countries with the support of German Agency for International Cooperation (GIZ) in close collaboration with the Secretariat of the Pacific Regional Environment Programme (SPREP) and with technical support from the International Union for Conservation of Nature (IUCN).

These efforts to support improved management of marine and coastal biodiversity on the volcanic islands of Fiji, Solomon Islands and Vanuatu and the atolls of Kiribati and Tonga will help countries to meet their commitments under the Convention on Biological Diversity (CBD) Strategic Plan 2011–2020 and the relevant Aichi targets, including the Programme of Work on Protected Areas and the Programme of Work on Island Biodiversity.

All five countries are working towards achieving the quantitative Aichi Target 11: 10% of the coastal and marine environment in protected areas by 2020[2]. As of 2014, the MACBIO countries had protected the following percentages of their marine and coastal environment: Fiji = 2%; Kiribati = 11%; Solomon Islands = > 5%; Tonga = 2%; Vanuatu = > 1%. With the exception of Kiribati, the countries remain a long way from achieving this Aichi target. Most of the existing MPAs are not ecologically representative and countries lack the means to ensure the conservation and sustainable use of resources. Most countries are facing severe challenges in regard to human resources and funding, inadequate law enforcement and lack of access to the information needed for marine biodiversity management.

Under the MACBIO project, IUCN Oceania is primarily responsible for conducting national-scale economic assessments of marine and coastal ecosystem services in all five MACBIO countries, including conducting a data gap analysis. National reports on the value of marine and coastal ecosystem services will be provided to countries to inform marine spatial planning and marine resource management in general. This is one of those reports.

2 Aichi Target 11: By 2020, at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

1.2 PROBLEM STATEMENT

Although the people and economies of the Pacific Island countries depend to a large extent on marine and coastal ecosystems, marine resource management should receive more 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 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 (subsistence)
- 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 service stocks and 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 species diversity. This, in turn, will help to sustain the benefits that people derive from those marine and coastal ecosystems.

1.3 PURPOSE AND OBJECTIVES

The MACBIO project has undertaken national economic assessments of marine and coastal ecosystems in the five project countries in a manner compatible with the global The Economics of Ecosystems and Biodiversity (TEEB) initiative. The work aims to contribute to national development plans and marine resource management policies and decision-making.

The principal objective of the economic component of MACBIO was to help countries to identify, quantify and, as far as possible, value in monetary units the most relevant marine and coastal ecosystem services in each MACBIO country. This should result in a national assessment of the human benefits of 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 within the reports can be used to guide, design and develop marine resources management plans, policies, assessments, legislation and tools, such as MPAs and environmental impact assessments.

This economic valuation is intended to enhance ecosystem-based marine and coastal resource management to 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 to securing and strengthening local livelihoods and food security.

1.4 DESCRIPTION OF THE GEO-POLITICAL BOUNDARIES OF ANALYSIS (SCOPE)

With an area of 180 million km^2 the Pacific represents around 50% of the global sea surface and a third of the Earth's surface. The 22 Pacific Island States and Territories comprise more than 200 mountainous volcanic islands and some 2,500 flat islands and atolls. The Exclusive Economic Zones (EEZs) of the five project countries cover about 7,560,000 km^2, an area the size of Australia. The project region is one of the world's centres of marine biodiversity, with an unusually large number of endemic species. Despite the outstanding importance of this biodiversity for people's food and livelihoods, comprehensive species and habitat inventories are often lacking, as well as adequate valuation of the ecosystem services they provide to people.

MACBIO adopts a national-scale assessment of the economics of ecosystem services and biodiversity as a direct result of the factors that contribute to a lack of appropriate information to manage the natural wealth of Pacific Island nations.

In Vanuatu we chose to conduct a national assessment in part because it would have the largest and broadest potential relevance to policy and decision-makers. Furthermore, the human resources and funding required to conduct valuations specific to each policy or initiative related to the marine environment are unlikely to be available in small Pacific Island countries. An overview of the national value of marine and coastal ecosystem services can be used in a variety of ways, in a manner that policy-specific analyses cannot. Consider, for example:

- Although subsistence marine and coastal resource use and management primarily takes place at the village or community level, it does so within an economic and policy context at a national scale.
- Commercial fishing is often managed at the national scale (if not the regional (international) scale).
- Infrastructure investment decisions to mitigate disaster risk in coastal zones are often best managed through national planning processes in this region.
- Most Pacific Island nations have only one international airport, one main deep water port and one primary commercial centre, so any economic development policy relying on these (e.g. to do with marine tourism) becomes an issue of national policy.
- Many Pacific Island nations have committed to national planning and policy efforts under one or more UN Conventions. National-scale capacity-building, data collection, storage and analysis will help to reduce redundancy and perhaps create synergies with other parallel efforts and country-scale commitments in the region.
- Many of the compensatory and regulatory policy tools available and being used to promote behaviour in line with both natural wealth management and sustainable economic development objectives are most often national-level tools. These might include payment for ecosystem services approaches, entry and/or exit fees, hotel taxes, taboo seasons, catch limits, use of coral for construction materials, clearing of mangroves, water, sewage and solid waste disposal, among other issues and concerns.

1.5 REPORT INTRODUCTION

This report provides details of the country-specific context within which the economic evaluation was conducted and then explains the methodological framework for the analysis. The specific methods applied in the report are discussed briefly; see Salcone et al. (2015) for the detailed methods. This report depends mainly on existing data and reports, synthesises this information and draws conclusions where possible. In the process, the work has revealed important knowledge gaps and future high priority data collection steps.

This study focused on economic valuation of a range of marine and coastal ecosystem services at a national scale. Specifically, the study team conducted desktop reviews to determine the commercial uses of marine resources (subsistence and commercial fisheries, tourism and mining) and assess their *economic value*. The team also conducted a desktop review of indirect uses of marine ecosystems (coastal protection, carbon sequestration, research, education and management) and assessed, as far as possible, their *economic value*. Figure 1 illustrates the ecosystem services analysed in Vanuatu. At the minimum, the human benefits from marine and coastal ecosystems are described in detail. Following identification and description, marine ecosystem services are quantified, if data are available, and, where possible, economic valuations for the marine services are provided.

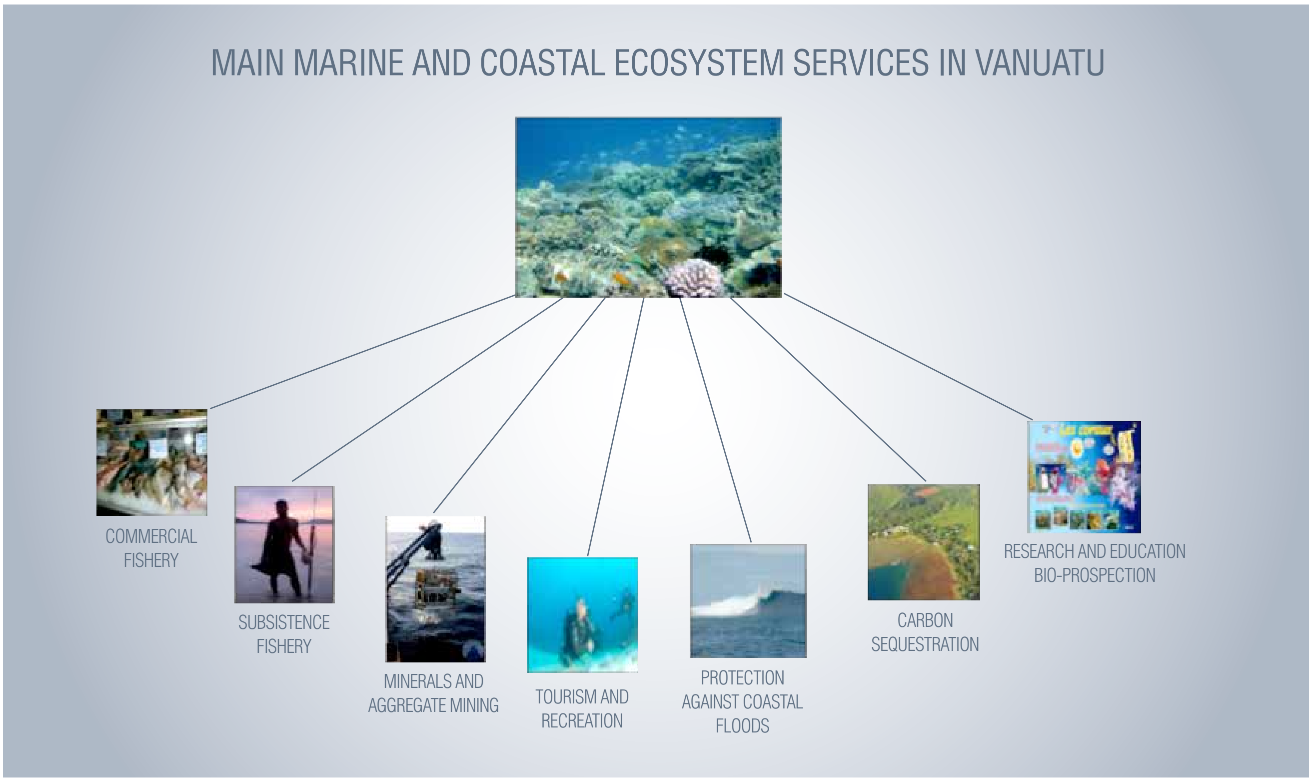

FIGURE 1 • Selected marine and coastal ecosystem services in Vanuatu

This report presents results for the following ecosystem services:

- Subsistence fishing, corresponding to the non-commercial fishery where all catch is consumed, given or exchanged but no monetary transaction takes place[3]. Fishing for ceremonies for specific events or celebrations form part of the subsistence fishery[4].
- Commercial fishing, including professional and non-professional inshore fishers well as pelagic fisheries and sport fishing. This fishery corresponds to all capture of pelagic, deep sea, nearshore and inshore reef and mangrove fish and invertebrates sold for food or for shells. Food can be sold as fresh or prepared (e.g. *laplap*).
- Mineral and aggregates extraction includes mining for aggregate and for polymetallic seafloor massive sulphides (SMS) found at sub-sea hydrothermal vent sites) which could contain significant quantities of copper, gold, zinc, silver and other commercially viable minerals.
- Tourism, covering all activities linked to coastal ecosystems such as underwater tourism, day tours and recreational boating in Vanuatu (mainly in Efate and Santo). The accommodation expenses associated with these activities are also included.
- Protection against coastal flooding. Coral reefs and mangroves are natural barriers to coastal storms and lessen the damage of severe weather events. In this study, we identified the role of marine ecosystems as well as the value of the damage avoided due to their presence.
- Carbon sequestration. Seagrass and mangrove ecosystems store carbon in living biomass and soil. Based on available habitat data, we quantified and valued the stock of carbon sequestered.
- Research, education and management. Marine and coastal ecosystems attract official development aid conservation projects as well as scientific research from around the world. They also offer education opportunities to students of all ages. The details and value of these projects are described.

3 This definition also applies to the recreational fishery, which was not included in this analysis.

4 Even if monetary transactions occur, fish sold in the village during fund-raising activities have been included in this category due to the low (below market) price of fish.

For each of these ecosystem services, the study provides a quantification and economic valuation (where possible) of the service as well as an identification of the main beneficiaries. An assessment of the sustainability of current use of each ecosystem service is also presented.

In the methods section, we discuss the methods used for estimating values of ecosystem services.

We also address the following considerations:

- We estimated the potential versus the sustainable level of the ecosystem service. The estimation of a monetary value to characterise the ecosystem service (e.g. fishery, tourism, mining) must be contextualised with information about environmental sustainability and the potential of the ecosystem services evaluated.
- We distinguished between ecosystem processes and systems. We defined core ecosystem processes and beneficial ecosystem processes, and how the latter are involved in producing ecosystem services to humans.
- Understanding and addressing ecosystem connectivity. Because coastal habitats are biologically linked, we had to allow for the effect of connectivity on our assessment of the ecological functions underlying key ecosystem services (e.g. fishery, coastal protection). In that sense, no individual valuation per ecosystem (coral reef, mangroves, seagrass, open ocean, sea mounts) is presented. Results are provided for each of the seven ecosystem services and a consolidated valuation summarises both the economic valuation and the quantification of the beneficiaries.

The report provides some recommendations and identifies next steps to be taken.

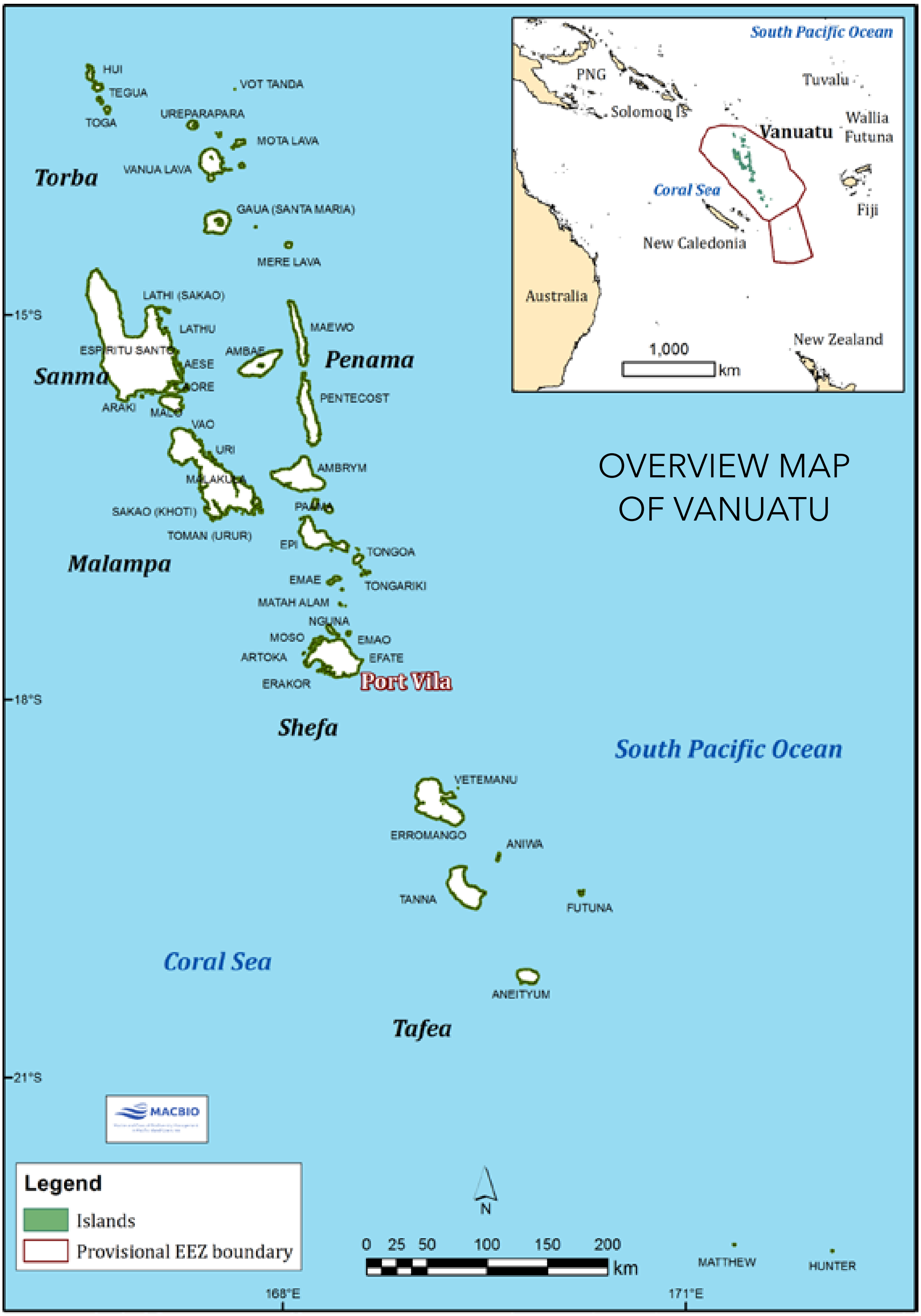

FIGURE 2 • Map of Vanuatu

2. CONTEXT

2.1 DEMOGRAPHIC AND ECONOMIC COUNTRY PROFILE

The Republic of Vanuatu is an archipelago of 82 islands in Melanesia that is inhabited by approximately 224,000 people (Figure 2). The country is a parliamentary democracy founded in 1980 after a history of colonisation by France and Great Britain. The country recognises French, English, and Bislama as its national languages, but there are more than 130 distinct languages spoken by different members of the ni-Vanuatu. Vanuatu's economy has had a turbulent history as the country struggled to establish sound economic policies. In 2003, the government passed a series of institutional reforms designed to encourage economic growth, including deregulating the airline and telecommunication industries. The reforms were successful and GDP growth averaged approximately 5% annually from 2003 to 2010. The country's economic growth has been sustained by strong contributions from the tourism, services, construction, and real estate industries (ADB 2009). The country's demographic growth rate is among the highest in the Pacific (ADB 2009) but the growth of the economy outpaced population growth, increasing per capita GDP.

Tourism is the largest *revenue*-earning industry in the country and economic growth will need to be at least partially achieved through the expansion of the tourism industry (Klint et al. 2012). This will create challenges not only for urban communities, which will need to make investments in infrastructure and labour while conserving natural resources, but also to rural communities who must protect their cultural and natural heritage (Verdone and Seidl 2012).

Vanuatu's fisheries are predicted to come under increasing pressure (Bell et al. 2009). The country's demand for fish is expected to increase by 147% and 37% in urban and rural areas respectively. Meeting this demand will require careful resource stewardship to maintain the health and resilience of fish stocks. This is especially important for rural communities that disproportionately rely on marine resources for their livelihoods.

The Household Income and Expenditure Survey (VNSO 2012) estimated the average income of rural households in Vanuatu at approximately US$ 500[5] per household per month. This *revenue* is equivalent to international US$ 1100 adjusted for *purchasing power parity* (Heston et al. 2011). Approximately 30% of this income comes from subsistence production.

2.2 INSTITUTIONAL CONTEXT

This section summarises the parts of government with responsibilities that impact on marine resource management and conservation and that could use marine ecosystem service valuation data.

Prime Minister's Office — The Office is responsible for the national development plan which sets the tone and priority of natural resource management including marine resource management. The office also gathers data on major sectors (i.e. agriculture) but not subsistence values.

Department of Environment Protection and Conservation — Environmental impact assessment is used in Vanuatu to put monetary values on damage to ecosystems, but not to put a value on healthy ecosystems. The department has studied wetland ecosystem services and made lists of what services they provide; they have also done limited biodiversity assessments in protected areas.

Department of Fisheries — This department is responsible for all aspects of management of Vanuatu's fisheries. The main fisheries concerns are the coconut crab (managed under the *Fisheries Department Act (2000)*) and the *bêche-de-mer* for which a Total Allowable Catch system is being established. Coastal fisheries, more generally, are of concern in Vanuatu; development of a Coastal Fisheries Management Policy was initiated in 2014.

Department of Forestry — The department's jurisdiction includes mangroves. The department has conducted some carbon accounting exercises putting financial prices on ecosystems (including mangroves), but on a very small scale. Forestry has conducted stock assessment of forests (mainly assessing the value of timber).

5 Conversion based on exchange rate of US$ 1= Vt 89

Department of Tourism — Tourism in Vanuatu is an important source of *revenue* and is largely reliant on marine resources. The department conducts strategic planning for tourism development and, to inform this effort, produces quarterly reports and data on incoming and outbound tourists and the main purpose of visits, etc. The importance of the ecosystems on which much of the tourism value is based is not assessed.

Vanuatu National Statistics Office (VNSO) — Social statistics gathered by VNSO include data on education, health and the labour force. Fishing activities are also measured. For example, there is quarterly information on commercial catch, information on fishing tax and fishing licences but no information on subsistence catches.

Public Works Department — The department is responsible for public works which can often have impacts on the marine environment. Small collections of natural resources are quantified but not entire ecosystems. For example there is compensation offered for resources that are destroyed when new roads are constructed and there is a standard rate for the destruction of a coconut tree or sandalwood tree, but this does not represent an entire ecosystem.

Department of Geology and Mines — This department is responsible for deep sea mining. They also provide estimates on hectares of land used to start quarries.

Although Vanuatu is governed by a parliamentary democracy, village chiefs have an important role in decision-making at the village level, including decisions about the management of marine and coastal resources.

2.3 POLICY CONTEXT

The Constitution of the Republic of Vanuatu 1980 recognises the significant requirement to safeguard the national wealth, resources and environment for current and future generations. Beyond this, there are many pieces of legislation and subordinate plans and policies which are pertinent to the use and management of the marine ecosystems of Vanuatu, most of which could be implemented in a more informed manner with additional information on the value of those ecosystems. The most relevant legislation and policies are:

NATIONAL LEGISLATION

- *Maritime Zones Act* No. 6 of 2010
- *Convention on Biological Diversity (Ratification) Act* No. 23 of 1992
- *Environmental Protection and Conservation Act* [CAP 283]
- *Fisheries Act* No.10 of 2014
- *Agreement Establishing the South Pacific Regional Environment Programme (SPREP) (Ratification) Act* No. 21 of 2005
- DSM Legislative Review Vanuatu 2013
- *Framework Convention on Climate Change (Ratification) Act* [CAP 218]
- *Maritime Conventions Act* [CAP 155]
- *Mines and Minerals Act* [CAP 190]
- *National Parks Act* [CAP 224]
- *Shipping Act* [CAP 53]

INTERNATIONAL CONVENTIONS

- UNCBD Strategic Plan: Aichi Targets

NATIONAL POLICIES, STRATEGIES AND PLANS

- Priorities and Action Agenda 2006-2015
- National Environment Policy
- Tuna Management and Development Plan
- National Biodiversity Strategy and Action Plan, 1999
- National Adaptation Programme for Action
- Integrated Coastal Management Framework and Implementation Strategy, 2010
- Plan of Work on Protected Areas (Not submitted yet according to CBD website)

- Climate Change Policy draft 30 January 2015
- Coconut Crab Management Plan
- National Marine Aquarium Trade Management Plan
- An analysis of the relevance of these laws, plans and policies is discussed in detail in Dovo and Muldoon (2015).

2.3.1 POLICY APPLICATIONS FOR MARINE ECONOMIC EVALUATION

Many discussions were held with government staff in Vanuatu regarding the both the concept and future use of economic valuations of marine ecosystems. In particular, the application or development of policies, plans and legislation were discussed. These discussions took the form of one-on-one conversations and workshops.

FIGURE 3 • Workshop participants at an Ecosystem Services Valuation workshop held in Port Vila, Vanuatu (February 2015)

An initial workshop (September 2014) in Vanuatu discussed emerging issues such as overfishing of a certain species and development trends. A follow-up workshop (February 2015; Figure 3) identified additional uses of the economic valuation results (see participant and meeting lists in Appendix II: Record of meetings and workshop participants). It was clear that both government and non-government stakeholders at the workshop were interested in understanding valuation of marine resources and a process to quantify the monetary value of Vanuatu's ecosystems. Some of the main uses for economic valuation of Vanuatu's marine and coastal ecosystems that were identified were:

- to build the value of subsistence fishing into decision-making because sometimes decisions made are based on erroneous, incomplete or no data
- to better integrate marine biodiversity values into planning by all government agencies directly involved with policy development that impacts on marine resources e.g. tourism
- to inform the development of the Coastal Fisheries Policy
- to assess the relative pros and cons of alternative development and/or management actions
- to contribute to national planning
- for use in environmental impact assessment processes
- for vulnerability assessments, spatial planning and other initiatives in the area of disaster risk reduction
- to inform decisions about compensation for damage to marine ecosystems
- to contribute to ecosystem-based approach projects e.g. Global Environment Fund (GEF) Integrated Sustainable Water Resource and Wastewater Management project
- to justify budgetary items to the Department of Finance

- to evaluate the impact of crown-of-thorns starfish on communities/reefs
- to revise fines and penalties
- to develop means to assess the relative value of biodiversity or ecosystem services versus threats such as invasive species
- to better justify the protection of mangrove ecosystems and healthy coral reefs
- to inform the development of an Oceans Policy.

There was also a desire to:

- increase human and technical capacity in economic valuation
- use the existing work as a basis to undertake more comprehensive economic valuation studies or complement work on specific project sites
- ensure the independence of analyses that quantify marine resources (vested commercial interests were identified, e.g. to do with deep sea mining and tuna fishing, that are inappropriately leading quantification of marine resources)
- centralise the location for economic valuation data storage (e.g. National Statistics Office), or encourage ministries to improve data storage and management
- cross-match economic valuation results with national statistics databases.

2.4 RELATED PROJECTS AND INITIATIVES

Within Vanuatu there are ongoing projects or initiatives with similar or related goals. They are described here to identify points of leverage, collaboration or synergy. MACBIO data identification and the national economic assessment provided here may serve as valuable contextual information or *baseline* values for these projects or provide additional complementary information.

Fish Aggregating Devices

GIZ and the Secretariat of the Pacific Community (SPC) have measured income to fisherman using Fish Aggregating Devices (FADs).

Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL)

In conjunction with the Department of Environment Protection and Conservation, this project has conducted a socioeconomic valuation of mangrove ecosystems. Two sites have already been completed — Eratap and Crab Bay.

Live and Learn

The NGO Live and Learn works with communities to put dollar values on the services they obtain from their forest by asking what it would cost the community if they could not get those services due to deforestation. Live and Learn has developed a cost-benefit analysis comparing conventional logging and carbon unit sales and has developed methods for calculating carbon sequestration services provided by protecting forest that would be logged, by reforesting land with mixed species trees, or by moving a community's main source of income away from copra (which leads to deforestation) to sustainable land management (e.g. value-added nut production, agroforestry, carbon incomes). They have also conducted a small survey on socioeconomic impact of movement to sustainable land management livelihoods (baseline only).

Restoration of Ecosystems Services against Climate Change Unfavourable Effects (RESCCUE)

RESCCUE, a project run by the SPC, is a five-year initiative to support integrated coastal zone management using economic tools. RESCCUE will conduct ecosystem service valuation as necessary to inform management plans and develop sustainable bio-finance mechanisms at pilot sites in French Polynesia, Fiji, Vanuatu and New Caledonia. Other projects of relevance include:

- Pacific Adaptation to Climate Change Cost-Benefit Assessment study (coastal infrastructure)
- United Nations Development Program (UNDP) Building Climate Resilience Project
- Melanesian Spearhead Group Alternative indicators of wellbeing for Melanesia project

- Vanua Tai Resource Monitors
- Vanuatu Cultural Centre (VKS) cultural sites listing
- Oceanwatch assessments
- REDD+[6] study (Santo)
- Global Environment Fund Pacific Alliance for Sustainability (GEF-PAS) conservation project
- Blue Carbon study
- Work on MPAs in North Efate.

In addition, there are a number of international, regional and sub-regional commitments, projects and/or initiatives that are relevant to this work.

Sustainable use and conservation of marine and coastal biodiversity are priority action areas of the Strategic Plan of the CBD. The Pacific CBD member states (including Vanuatu) have expressed their commitment to the implementation of the extensive CBD resolutions on the conservation and sustainable use of marine and coastal biodiversity.

In this regard the project responds to the needs of Vanuatu by:

- assisting the government to achieve the Aichi targets as a contribution to the CBD Strategic Plan for Biodiversity 2011–2020.
- implementing actions outlined in Vanuatu's National Biodiversity Strategies and Action Plan.
- contributing directly to the CBD Program of Work on Protected Areas, especially to attainment of Aichi Target 11.
- assisting with implementation of the CBD Program of Work on Island Biodiversity in accordance with the CBD COP 11 decision.

Beyond the CBD, Vanuatu has other commitments, interests and projects that this report can contribute to by, for example:

- contributing to implementation of the Pacific Regional Environment Strategic Plan 2011–2015
- implementing some of the principles for regional integration and cooperation for the purpose of conserving marine resources formulated in the Pacific Oceanscape Framework and supported by high-level decision-makers
- initiating a System of Environmental-Economic Accounts (green national accounting)
- contributing to other projects, such as Ridge-to-Reef and RESCCUE.

Through its implementation partners the project is a member of the Marine Sector Working Group of the Pacific regional organisations (Pacific Island Forum Secretariat (PIFS), SPREP, SPC, and the University of the South Pacific) and locally active international environmental NGOs. This allows for project activities to be coordinated with projects in other target countries and to serve as an example in other Pacific Island States and Territories.

The transferability of successful approaches is enhanced by involving representatives of other regional institutions and by running workshops at regional events attended by all Pacific Island states, such as the Pacific Climate Change Roundtable and the Pacific Island Roundtable for Nature Conservation.

Dissemination of the knowledge gained from the project and its incorporation into global and regional processes is promoted through continuous dialogue with relevant global institutions (TEEB Global, UNEP World Conservation Monitoring Centre, European Union (EU) Joint Research Centre and IUCN World Commission on Protected Areas) and cooperation with ongoing BMUB International Climate Initiative projects in the field of marine and coastal biodiversity.

6 REDD+ is a United Nations initiative aimed at Reducing Emissions from Deforestation and Forest Degradation.

3. CONCEPTUAL FRAMEWORK

The primary purpose of this assessment was to provide decision-makers and policy-makers (at all levels) with information about the value that people place on their marine and coastal ecosystems. This was with a view to inform the development of those decisions and policies with more concrete information about marine ecosystem values that are otherwise not fully appreciated or considered. 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 within Vanuatu (see Appendix II: Record of meetings and workshop participants).

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 (cf. Figure 4). These benefits could be material goods such as timber or fish, or biological 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 Fijians is a powerful tool to make these benefits visible and improve their wise use and management. The process of assigning monetary values to ecosystem services that benefit people is called *economic valuation*.

PROVISIONING	REGULATING	CULTURAL
• Seafoods • Building Materials • Minerals	• Coastal Protection • Carbon Sequestration	• Tourism • Recreation • Cultural Identity
• Nutrient Cycling	SUPPORTING • Photosynthesis	• Habitat

FIGURE 4 • Marine ecosystem services

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[7]. While *economic activity* from market transactions is often used to calculate *economic value*, *economic activity* is not in and of itself a measure of human benefit. *Economic activity*, however, is an interesting measure[8]. The number of formal sector jobs and the likelihood of capital investment are closely related to *economic activity*, and this is of interest to the

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

8 GDP, produced through the System of National Accounts (SNA), is a measure of *economic activity*. The UN Statistics Division 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.

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.

In assessing and comparing ecosystem services, there are sometimes 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.

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; *consumer surplus* is the benefit received by individuals who purchase or freely enjoy a good or service. 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' benefit from the transaction. Consumer WTP is represented graphically as a demand curve.

Total economic value

The *total economic value* of an ecosystem service includes all of the net benefits humans receive from that ecosystem service. *Total economic value* is a quantification of the full contribution ecosystems make to human wellbeing. *Total economic value* includes *market value* 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 functions*.

In practice, *total economic value* is nearly impossible to calculate 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 *total economic value* of the fishery is a sum of the producer and consumer benefits. However, consumer benefits are 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 represent *total economic value*.

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

3.2 THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY

As an implementing partner on the MACBIO project, IUCN Oceania is responsible for national-level assessment of marine and coastal ecosystem services in Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu. These national reports on marine and coastal ecosystem services follow the approach for assessing ecosystem services developed by the TEEB initiative (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

The MACBIO model for economic assessment of ecosystems was to conduct research in partnership with local organisations and government representatives to improve their capacity to analyse and synthesise ecosystem valuation data. In addition, this collaborative approach contributed to in-county understanding of, and belief in, the results of the ecosystem service valuations. Capacity development included basic training on resource economics concepts, recommendations for modifying or improving data collection, discussions about how economic service valuations could be used in government and elsewhere and ongoing monitoring and evaluation of ecosystem service values to achieve sustainable development. To this end, the ecosystem service valuation included the participation of government staff and local resource managers to permanently augment the capacity of country nationals to use ecosystem data and economic valuation in development of policies and resource management decision-making.

Stakeholder workshops and meetings were held to identify specific applications for the economic valuation in Vanuatu including the policy issues that could be supported by more information about the values of ecosystem services (TEEB Step 1). The policy issues identified by stakeholders covered a wide range of topics (see Section 2.3.1). Given the resource constraints in these small countries, it was deemed unlikely that a detailed marine economic service valuation would be conducted for every policy context described. It was decided, therefore, to conduct a more generic marine ecosystem service valuation which could be used in whole or in part to inform a range of different existing and potential policy and decision-making situations in Vanuatu. These workshops, and individual discussions and existing documentation, helped to identify the most relevant ecosystem services per country (Step 2).

Steps 2–6 were conducted by IUCN staff with in-country colleagues following the approach of the TEEB initiative. TEEB encourages economic valuation practitioners to engage with stakeholders not just to identify needs and policy applications for the ecosystem service valuation but also to develop methods for valuation that meet those particular needs and to ensure that the data provided are useful and relevant. In addition, in-country colleagues advised about the best way to communicate the results to relevant stakeholders. This report forms the basis for any communication products.

A methodological guidance document (Salcone et al. 2015) was created in consultation with the country-based research teams to ensure consistent treatment across the five study sites, as far as possible.

It is anticipated this initial *baseline* 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 service stocks, 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 of different management decisions; 2) as a technical tool to set prices for protecting resources or compensation for ecosystem damages; 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 — general information for planning and advocacy.

During workshops and other discussions stakeholders explicitly identified a range of uses of the marine ecosystem valuation results for Vanuatu (see Section 2.3.1).

4. LITERATURE REVIEW

Published work on marine ecosystem service valuation in Vanuatu is limited, particularly in the peer-reviewed literature.

Site-specific studies in Crab Bay and Eratap found that mangroves in Crab Bay had an estimated *total economic value* of US$ 596,351 per year and that Eratap mangroves had an estimated *total economic value* of US$ 270,698 per year. Crab Bay mangroves were valued at US$ 4,375 per hectare per year, and Eratap mangroves were valued at US$ 781,566 per hectare per year. The values included those associated with fisheries, wood extraction, tourism, protection against waves, bioremediation, sediment trapping and carbon sequestration. Methods used included surveys of local fishers and calculation of *market values*, *avoided costs*, *replacement costs* and *willingness-to-pay*. Nearly 800 people depended on one or more mangrove ecosystem services in Crab Bay; 400 people depended on mangrove services in Eratap (Pascal and Bulu 2013).

The same study estimated the net *economic value* of subsistence, commercial and recreational fisheries at Crab Bay and Eratap. On average in Crab Bay, subsistence fisheries were valued at US$ 1,334 per hectare and commercial fisheries at US$ 851 per hectare (recreational fisheries were non-existent in Crab Bay). In Eratap, subsistence fisheries were valued at US$ 2,914 per hectare, commercial fisheries at US$ 1,382 per hectare and recreational fisheries at US$ 78 per hectare. Values were calculated by conducting a business expenditure survey of fishers, quantifying catch volumes and examining the replacement price of fish protein as well as final consumer prices (Pascal and Bulu 2013).

There have been a few regional studies of the value of ecosystems and ecosystem services throughout the Pacific Islands region. 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 per square kilometre per year (2014 dollars). 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 within 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).

In a report prepared for the Asian Development Bank (ADB), the Pacific Islands Forum Fisheries Agency (FFA) and the World Bank, 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 was estimated at more than US$ 2.29 billion per year (2014 dollars, from Gillett 2009). This value was estimated to contribute as much as 10% of gross domestic product in the region. Pacific Island States and Territories received an additional US$ 89.6 million per year in access fees and other charges to foreign fishing vessels. This amount has increased substantially since this report was published. Of this value, coastal commercial fisheries contributed an estimated annual value of US$ 183.1 million, and coastal subsistence fisheries an estimated annual value of US$ 221.4 million. These values were based on fish prices at the dock (adjusted to 2014 dollars from Gillett 2009). The same report estimated that the annual value of offshore fishing in all Pacific Island States and Territories in 2007 was more than US$ 1.7 billion, including more than US$ 681 million per year for locally-based fisheries and US$ 1.23 billion per year for foreign-based fisheries. These values were also based on dockside prices (adjusted to 2014 dollars from Gillett 2009). Most of the value of inshore fisheries and some of the value of locally-based offshore fisheries accrued within the countries. Most of the value of the foreign-based fishing accrued to the foreign fleets and foreign countries where the catch was unloaded.

According to a later study for the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, the total estimated annual value of delivered tuna captured in the Western and Central Pacific Ocean, based on prices paid at the processor, was US$ 7.4 billion (in 2014 dollars). This amount included *value-added* through transportation and initial processing. Tuna caught using purse seine nets accounted for 56% of the total value; tuna caught in the longline fishery made up 27%. Skipjack represented 49% of the total value; yellowfin made up 30%; bigeye accounted for 15%; and albacore was just 6%. In 2012, fishers caught more than 2.6 million tonnes of tuna, the highest volume on record and 59% of the global tuna catch (WCPOC Scientific Committee 2013).

5. METHODS

The general methods are presented in Salcone et al. (2015). Specific details of methods applied in this report are presented below or in the relevant sections of the report.

As far as possible, government staff and other relevant parties within Vanuatu worked with the authors to answer questions, supply information and data and to identify data gaps for this report (TEEB steps 1–4). See Appendix II: Record of meetings and workshop participants for the list of people consulted. These colleagues also identified in-country policies, plans, strategies and other marine resource management tools to which this work could contribute (see Section 2.3.1).

5.1 OVERVIEW OF ESTIMATION METHODS

This analysis identified seven key marine and coastal ecosystem services that are described and valued in this report:

- Subsistence food
- Commercial food
- Minerals and aggregate
- Tourism and recreation
- Coastal protection
- Carbon sequestration
- Environmental research, management and education

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

The detailed and specific mathematical methods and data requirements for estimating the value of these seven marine and coastal ecosystem services are provided in Salcone et al. (2015). This is a methodological guidance document created in consultation with the country-based research teams and other Pacific resource economists to ensure consistent treatment across the five study sites.

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. Where sufficient 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 value or references to other locations with data on the identified values. Gaps in data and previous research are partially offset by the authors' judgment based on economic theory.

Introductions to specific methods used to value each of the seven ecosystem services are given in Chapter 6. Information in the report that has no citation or source is based on the personal knowledge of the authors. Similarly, in some cases, unpublished data were sourced from government departments and have no further reference.

Unless otherwise stated, all values have been converted to 2013 US dollars (US$) and local Vatu (Vt). Currencies are converted using the most appropriate method to facilitate comparison of the magnitude of the benefits or costs, using price or currency *inflation* indices. An exchange rate of Vt 89 to US$ 1 is used throughout the report.

Within the methods, it was necessary to consider the following issues:

How do we deal with potential vs sustainable levels of subsistence fisheries, commercial fisheries, mining of aggregates and minerals, and tourism?

If actual yields surpassed the maximum sustainable yield (MSY), we only considered that part of the yields below MSY. The underlying aim was to limit this valuation to ecologically sustainable activities.

The limited information available for mining of aggregates and minerals and the paucity of references in the literature made it difficult to obtain an accurate estimate of sustainable volumes of sand extracted or exploitation of minerals.

For tourism, we considered the number of tourism visits (less than 100,000 in 2013) and calculated visitation rate (number of visitors per hectare of reef per year) at the main tourism sites in Efate and Santo (the two main underwater destinations). We compared this number to international references on intensity of reef recreation (Hawkins and Roberts 1992; Scura and van't Hof 1993; Davis and Tisdell 1996; Harriott et al. 1997; Barker and Roberts 2004; Uyarra et al. 2008; Hasler and Ott 2008). The results indicated a relatively low visitation rate, which suggests a very low risk of overexploitation. We assumed therefore that economic values obtained for this ecosystem service (*producer surplus*) are sustainable.

What is the spatial distribution of ecosystems, and how would it affect the analysis?

The analysis could have been done by considering the locations of ecosystem processes, the locations of human activity, or the locations where benefits are transformed into money. We also had to address the spatial extent of any knowledge gaps for marine ecological processes. Considering the complexity of these processes, we relied on the most recent scientific results and chose to assess the place where human activity occurs. This is addressed per ecosystem service in Chapter 6.

Correction factor for subsistence fishery

In the case of the subsistence fishery, we chose to measure ecosystem benefit using weight of protein equivalent as a proxy and to convert to a monetary value using the market price of protein equivalent. This approach does not consider many aspects of subsistence fishing. For example, benefits not reflected in the valuation include: (i) the fishing activity requires small investment and little training (Vanuatu Environment Unit 2007); (ii) subsistence fishing can be a factor of social cohesion in villages because it contributes to women remaining in villages instead of seeking a cash income outside (Bensa and Freyss 1994); (iii) for some households the part of the protein obtained from fishing in the total diet is non-replaceable (Pollnac et al. 2000); and (iv) fishing is a stable food source that buffers against future uncertainties in food security (Johannes 2002). To reflect these benefits of the subsistence fishery, a weight-correcting factor of 1.3 is applied to the *value-added* (Seidl et al. 2011; Laurans et al. 2013).

The timeframe of the analysis

We focused on financial flows or economic values from 2013. When possible, we compared the calculated use value with data from the previous five years to identify potential biases and unrepresentative situations.

The effect of ecosystem connectivity

The analysis was done for all marine and coastal ecosystems without any individual valuation of specific ecosystems. The interconnectivity of ecosystems (e.g. mangroves, seagrass and coral reefs) makes it impossible to value each system separately.

5.2 SECONDARY DATA SOURCES AND QUALITY

The main sources of data for this study were existing literature and analysis of official statistics (Table 3) supplemented by collection of very specific data in the field.

TABLE 3 • Data sources and literature for Vanuatu

Services	Data source
Subsistence fishery	Amos 2007; Vanuatu Environment Unit 2007; Hickey 2008; VNSO 2008; Bell et al. 2009; Gillett 2009; VNSO 2012; Pascal and Seidl 2013; Vanuatu Fisheries Department
Commercial fishery	Dalzell 1990; Chambers 1990; Friedman et al. 2003; Vanuatu Environment Unit 2007; Hickey 2008; VNSO 2008; FFA 2009; Gillett 2009; VNSO 2012; Pascal and Seidl 2013; Vanuatu Fisheries Department
Minerals and aggregate	SPC Mining Division
Tourism and recreation	TRIP Consultants 2008; VTO 2009; Klint et al. 2012; Pascal and Seidl 2013; VTO; official statistics from Department of Ports and Marine
Coastal protection	Land Department GIS Database, VNSO
Carbon sequestration	Pascal 2014; Department of Environment
Research, management and education	Ministry of Economy

The main source of data to quantify fishery catches was the Household Income and Expenditure Survey (HIES) (VNSO 2012). The HIES 2010 was based on surveys conducted in 4,380 selected households representative of 91% of all estimated households in Vanuatu[9]. The survey was based on a logbook of daily expenses completed by the households[10] over three months. All household income[11] was reported as well as household expenditures[12]. Results are expressed as monthly values per household[13]. Details for sales, own consumption and gifts received are available for the main categories of fish (reef fish, shellfish, pelagic fish and tinned fish) for urban and rural households at the national level.

Following the HIES approach, estimated relative standard errors (RSEs[14]) for household income and expenditure were calculated. At the national level, the RSE estimates for non-consumption expenditures were less than 20% and considered to provide reliable estimates. RSEs for provincial monthly household incomes for seafood were higher (RSE > 30%) therefore provincial results should be used with caution. We concentrated our analysis on the national level (usable data with RSE < 20%). The RSEs were converted to standard deviations to calculate variation in household income estimates (both sales and subsistence use of seafood). A more detailed description of the method used is given in the HIES 2010 report (VNSO 2012).

The extrapolation of HIES results to an annual basis required some correction. The hot and wet season lasts from November to April and is characterised by higher temperatures. During this period fishing effort increases, as fishers can stay longer on the water and/or make more fishing trips. As described by Amos (2007), fishing activity is often correlated

9 There were eight main populations of interest or regions for which estimates were required from the 2010 HIES: the provincial rural areas of Torba, Sanma, Penama, Malampa, Shefa, Tafea and the urban areas of Luganville and Port Vila.

10 The household is defined as a group of people who usually live together and have a common arrangement for food, such as using a common kitchen or a common food budget.

11 Household income includes: (i) income from employment (both paid and self-employment); (ii) property income; (iii) income from the production of household goods and services for own consumption; and (iv) current transfers received.

12 Defined as the value of consumer goods and services acquired, used or paid for by a household through direct monetary purchases, own-account production, barter or as income in-kind for the satisfaction of the needs and wants of its members.

13 When a quantity was provided without a value, the value was imputed based on the value of transactions of the same commodity in the same location.

14 Relative standard error (RSE) is calculated by dividing the standard error of the estimate by the estimate itself. RSEs less than 30% are considered reliable.

with the agriculture calendar and the wet season corresponds to less crop activity. These two potential sources of bias are taken into account in the extrapolations through the application of correction factors on harvest estimates. Correction factors were deduced from a previous study (Anderson and Mees 1999), which surveyed a full year of fishing effort by the main fishing gear used. The correcting factor for HIES 2010 was 0.88 on the annual extrapolations of the monthly results. This factor reflects that HIES surveys were conducted during the hot season[15] when fishing effort is generally higher. Annual values have been converted to US$.

For tourism, estimates of the *producer surplus* of service providers and the expenditure per visitor were based mainly on the following sources:

- Surveys conducted during the IUCN-AFD *Cost-Benefit Analysis* of MPAs study (Pascal and Seidl 2013). A Business Expenditure Survey of main tourism businesses (described in Pascal and Seidl 2013) was used for *producer surplus* estimates. Interviews with tourism service providers (n = 8) included a sample of diving clubs and most of the day tour operators. For all business categories, information about business activity, *revenue*, cost structure and visitor profiles was collected[16].

Surveys took place during part of the cold (or dry) season, from June to November. This period is the high tourism season, affecting tourism flows. A correction factor of 0.8 was applied to the average monthly number of visitors to calculate annual visitor rates. This factor was based on interviews with tourism professionals and results from tourist exit surveys (TRIP Consultants 2008).

- The Vanuatu Tourism Office (VTO) exit survey of tourists (n = 500) conducted by the VTO in the airport in 2008 determined the characteristics of visitors, their activities and their main motivations (VTO 2009).
- The results of Pascal and Seidl (2013) provided the levels of *intermediate costs* for most tourism businesses. For tourist resorts and dive resorts, the estimated *value-added* was between 55% and 65%. For day tours, the average *value-added* was 55%, including benefits at village and national levels through the tour operators[17]. The *intermediate costs* of diving clubs are estimated to represent 45% of the *revenues*.
- The IUCN-AFD project (Pascal and Seidl 2013) was based on surveys (n = 85) with visitors including divers. Data collection occurred from April to October 2012. The objectives were to obtain information about their (i) main activities undertaken in the country, (ii) knowledge of the existence of the marine reserve, and the role of marine ecosystems in their visit with detailed data about their preferences during a dive and (iii) stay in the country (length, expenses, etc.).

5.3 DATA GAP ANALYSIS

The analysis of the literature for the valuation of the ecosystem services related to commercial and non-commercial fisheries revealed much. Qualitative descriptions of fishing effort, dependency on the resource and some indicators of recent trends are available. Quantitative statistics, such as annual catches, number of regular fishers and distribution of effort between commercial and non-commercial fishers, are more scarce and limited to specific places and times.

Very little data on tourism and recreational uses of marine ecosystems is available except for a generic description of the sector and activities related to the sea. Few studies have monitored the number of visitors to reefs or the motivation for their visits. Airport exit surveys with visitors have supplemented the data.

No data on financial results or permits for extraction of minerals and aggregates was publicly available to quantify the ecosystem service. Results presented in this report rely on qualitative values.

Similarly, the available data about carbon sequestration included qualitative studies describing general aspects of the processes, but no precise valuation of the amounts of carbon sequestered, nor mangrove habitat areas in Vanuatu were available.

Data on research, education and management were sourced from the Ministry of Finance with whom we were able to track the aid and grant flows into Vanuatu in 2013.

15 The HIES survey period was October to December 2010.

16 When possible, access to visitor guest books and private accountant books completed the data set for better estimates of quantitative figures.

17 Terrestrial day tour costs include transport and advertising. Benefits are shared between an operator based in the capital of Port Vila (90% of the *value-added*) and a village representative who redistributes the benefits to families in charge of restoration and the community.

5.4 SYNTHESIS AND EXTRAPOLATION

The value estimates in this study rely on existing literature, analysis of official statistics and collection of very specific data in the field. Data collection activities included direct observations in the field to update the valuations (e.g. counting the number of dive shops, number of marinas, etc.), data mining and formatting analyses to our needs (e.g. exchanges with the VNSO about the HIES) and direct requests to government institutions (e.g. Department of Environment and the Ministry of Finance for budgets on research, management and education).

Data gaps for commercial and subsistence fisheries and tourism were addressed by combining results of previous field surveys usually available for a specific place and time with national statistics (e.g. HIES, airport surveys with visitors) and expert knowledge. The valuation of carbon sequestration relied on sequestration rates from similar ecosystems in other countries. Details are given in the corresponding sections.

6. RESULTS

This section includes the identification, quantification, and where possible, valuation of Vanuatu's 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.

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 nations. The **Uncertainty** of each value estimate is also discussed in this section.

6.1 SUBSISTENCE FISHERIES

6.1.1 IDENTIFY

Several processes are identified in the production of biomass and protein for fisheries. We distinguish biomass production, maintenance of habitat complexity, the role of nursery areas and the connectivity of ecosystems. A more complete description of the ecosystem processes implicated in the production of this ecosystem service is given in Appendix III.

Local families, for whom fishing in the mangroves and on the reef is a source of regular protein, are the main beneficiaries of subsistence fisheries in Vanuatu. The HIES in 2010 estimated that more than 13,800 rural households (40% of rural households in Vanuatu) and 1,700 urban households (15% of urban households) catch fish for their own consumption. This is equivalent to more than 74,000 individuals dependent on the resource (approximately 32% of the population of Vanuatu) (VNSO 2012).

6.1.2 QUANTIFY

Subsistence harvests are used for family consumption (direct and extended family), to share with relatives or for the community through customary events and fund-raising activities[18]. Fishing activity seems to be well spread throughout the ni-Vanuatu population. The HIES conducted in 2010 (VNSO 2012) estimated that in Vanuatu, more than 75% of the adult population practice at least one form of fishing, whether subsistence or commercial. As described by several authors (Amos 2007; Hickey 2008; Bartlett et al. 2009) commercial fishing is a formal activity and represents, for most households, an irregular source of income complementary to agricultural activities. Distributions between subsistence and commercial activities are very different among villages and islands. In North Efate[19], fishing is clearly a source of protein with less than 30% of harvest sold in some villages (Pascal and Seidl 2013). Many households engaged in some form of fishing (almost 80% of the rural households in Vanuatu) and, for most, fishing activities complement other activities (e.g. salaries in town, crops, handicrafts). In a few villages, the fishery is primarily commercial and represents a source of cash.

There is no difference in target species or fishing techniques between subsistence fisheries and commercial coastal fisheries, except for the trochus (*Trochus* spp.) and *bêche-de-mer* (sea cucumber) fisheries. Trochus are collected

18 Fund-raising activities—when people sell prepared meals or fresh fish in their village to raise funds for community events or specific family events (e.g. weddings, school fees)—were considered as subsistence activities because the transactions have a low price (less than US$ 1 per ration of cooked fish).

19 Based on regular monitoring of fishery logbooks over the period 2010–2012.

specifically to be sold for their shells in the capital and *bêche-de-mer* is exported.

The three main types of fishing gear employed in subsistence fishing are gill nets, handlines and spear guns. This gear mainly targets species in families Scaridae (parrotfish), Acanthuridae (surgeonfish) and Serranidae (e.g. sea bass, grouper). The gill nets are used principally in the form of drive-in nets. Night spearfishing with diving lamps is common for targeting scarids, especially bumphead parrotfish (*Bolbometopon muricatum*), a threatened species (Chan et al. 2012). Fishing gear that is less commonly used includes cast nets (depending on the migration timing of some species), hand lines from the shore or canoe, hand collecting (common at low tide for octopus and shells) and other traditional gear (e.g. hand spear). Some fishing gears are used only by women (principally hand collecting and hand line from the shore). Trochus is collected with snorkel gear from the shore only when the fishery is open.

We have used multiple sources to determine the volumes and values of subsistence fish catches to improve the accuracy of the estimates. Our main source was the 2010 HIES (VNSO 2012) describing monthly income from sales of fish and shellfish and non-consumption equivalent income from subsistence catches. Other sources of estimates (Hickey 2007; Vanuatu Environment Unit 2007; VNSO 2008; Bell et al. 2009; Pakoa et al. 2013) were used to calibrate the results.

The *intermediate costs* associated with the two main fishing gears are estimated to represent approximately 20% of the value of the HIES catches (based on market prices). The methods described by several authors (Gillett and Lightfoot 2001; Kronen 2003; Kronen 2007) have been used to take into account all cost categories for the coastal fisheries activities (including equipment, maintenance, operation costs and fishing gear costs[20]).

6.1.3 VALUE

The *value-added* for own consumption of fish in Vanuatu is presented in Table 4. Reef fish represent approximately 80% of the fish consumption; the rest is made up of octopus, crab and shellfish.

HIES data provided monetary value for subsistence consumption, and fish catch volumes were estimated from these data. Average national market prices of reef fish and other goods were provided by the VNSO[21].

TABLE 4 • Volumes and value-added of subsistence fishery, 2010

	Subsistence catch (tonnes)	Annual value-added (US$)	Minimum (US$)	Maximum (US$)
Rural	2600	6,050,000		
Urban	200	440,000		
Total	**2800**	**6,490,000**	**5,840,000**	**7,140,000**

Source: VNSO 2012[22].

We reviewed different sources of literature including fishery department reports (FFA 2009), scientific papers (Cinner and Aswani 2007; Hubert 2007; Bell et al. 2009) and results from socioeconomic monitoring (Kronen 2003; David et al. 2007; Kronen 2007; Vanuatu Environment Unit 2007) to check the validity of the estimate. Despite the different methodologies used in the different studies[23], there was wide variability in estimates of the value of subsistence fishing among islands, sites, months and fishing gears. This is a common characteristic of small-scale fisheries targeting many species with many types of fishing gear. Table 5 illustrates this variability. All the villages are neighbours and have different levels of fishing effort. The variations in effort depend on many factors which are hard to predict (e.g. family traditions, access to reef, personal skills in fishing and business, attraction to the sea, family context, access to markets, financial facilities). This high variability in effort means that extrapolation of results of site-specific studies to the rest of the country will have low reliability (Table 6).

20 Equipment costs have been annually amortized on the basis of their expected life (10 years for fibreglass boats, 5 years for engines, 2 years for most fishing gear).

21 The following prices were used: Tuna/bonito: 230 Vt/kg, reef fish: 274 Vt/kg, crabs: 122 Vt/kg.

22 Note that there are margins of error for total values (from HIES, VNSO 2012) and therefore we are able to calculate minimum and maximum values, but there are no margins of error for categories (rural or urban).

23 Several methods were applied to the collection of fishery effort data: (i) logbooks self-reported by fishers; (ii) interviews with fishers (selected individuals or with groups); and (iii) regular monitoring of fish commercialisation (with transporters).

TABLE 5 • Monthly average fishing effort (hours) with different gear in five neighbouring villages

	Village				
Gear	**Emua**	**Siviri**	**Tanoliu**	**Mangaliliu**	**Tassiriki**
Line	15	7	23	11	12
Line – fishing boat					
Net	50	12	24	27	14
Spear	93	5	36	53	10
Overnight net					
Spear (night)	37	6	37	17	40
Gleaning	13	9	11	13	8

Sources: Kronen 2003; Cinner and Aswani 2007; David et al. 2007; Hubert 2007; Kronen 2007; Vanuatu Environment Unit 2007; Bell et al. 2009, Vanuatu Fisheries Department and Pacific Islands Forum Fisheries Agency 2014.

TABLE 6 • Annual catch estimates for five neighbouring villages

	Emua	Siviri	Tanoliu	Mangaliliu	Tassiriki	Vanuatu
Total annual catch (kg)	3,690	477	1,817	2,548	1,879	16,786
Minimum catch (kg)	2,583	334	1,272	1,783	1,316	11,750
Maximum catch (kg)	4,797	619	2,362	3,312	2,443	20,865
Catch/km^2 of fishing ground (t/km^2)	3.1	0.3	2.1	0.7	0.8	1.4
Per capita catch (kg/person)	7	3	2.9	5.1	3.2	4.0
Proportion sold	55%	20%	60%	60%	40%	43%

Sources: Kronen 2003; Cinner and Aswani 2007; David et al. 2007; Hubert 2007; Kronen 2007; Vanuatu Environment Unit 2007; Bell et al. 2009; FFA 2009.

Another method of verification is to use fish consumption per capita to estimate the value of subsistence fisheries. Recent studies have found that the annual level of consumption of fresh seafood in Vanuatu varies between 16 and 26 kilograms per person (VNSO 2008; Bell et al. 2009; Pascal 2010). Our estimate of fish catches for own consumption is equivalent to approximately 12 kilograms per capita per year, consistent with our total estimate of 2,800 tonnes of fish caught annually (based on a population of 235,000).

Similarly, estimates were compared with values in Gillett (2009) who estimated coastal subsistence catches of 2,830 tonnes per year in 2007, similar to our own estimates.

6.1.4 UNCERTAINTY

Data regarding small-scale subsistence fisheries present a high level of uncertainty (Laurans et al. 2013). Most of the activities are informal, sporadic and dependent on socio-ecological context. The fishery involves a high number of target species (multi-species fishery), fishing gears and habitats. This level of uncertainty is reflected in the gap between the minimum and maximum estimates of the valuation.

6.1.5 SUSTAINABILITY

For subsistence and commercial fisheries the obtained catches were aggregated and reported for each fishing ground area (in tonnes per km^2 per year) and compared to the reference value of 5 tonnes/km^2/year for MSY of reef fisheries (Munro 1984; Jennings and Polunin 1995; Newton et al. 2007; Mumby and Steneck 2008; Armada et al. 2009). The catch estimates provided in Table 6 refer to catches of 0.3–3.1 tonnes per km^2 per year of reef which may be sustainable. Nevertheless, there are many assumptions: that the subsistence catch is, in fact, most of the reef-based catch; that fishing is spread homogeneously over the reef area (which it is not); and that the catch estimated from records is correct (which it often is not, see Zeller et al. 2014). It has long been recognised that Pacific coral reef resources are vulnerable to overexploitation and only under exceptional circumstances can they support market fisheries (Bell et al. 2009). An assessment of whether there is localised depletion in the coastal fishery would require in-country surveys beyond the scope of this report.

For mud crabs, a maximum catch of 500 individuals per km^2 per year is taken as a very approximate reference (Villasmil and Mendoza 2001). Although yields in some areas likely surpass the MSY, only yields below MSY were considered. The underlying aim was to limit this valuation to ecologically sustainable activities only as, in the long term, the average annual catch logically cannot exceed that level of exploitation.

6.1.6 DISTRIBUTION

The subsistence fishery benefits accrue almost exclusively to the ni-Vanuatu. The distribution of the *economic value* of subsistence fishing per Vanuatu provinces is presented in Table 7. The distribution is based on the HIES results per provinces and provides some illustration of the beneficiaries. Discussions with Department of Fisheries in Vanuatu suggest, however, that the subsistence value of fisheries to Malampa may be greater than for Penama (G Nimoho, Department of Fisheries, pers. comm.).

TABLE 7 • Added value of subsistence fisheries per province

Province	Annual value-added (US$)	% of total
Torba	472,000	7
Sanma	1,523,000	23
Penama	1,133,000	17
Malampa	908,000	14
Shefa	1,109,000	17
Tafea	1,345,000	21
Total	**6,490,000**	**100**

6.2 COMMERCIAL FISHERIES

6.2.1 COMMERCIAL NEARSHORE FISHERIES

6.2.1.1 IDENTIFY

The main commercial nearshore fisheries in Vanuatu are the reef, pelagic and deep slope fisheries. Reef fisheries include the commercially important crab, trochus, *bêche-de-mer* and aquarium fisheries.

The ecosystem processes underlying the commercial reef fisheries are similar to subsistence fisheries. They cover biomass production, maintenance of habitat complexity, the role of nursery areas and the connectivity of ecosystems (see Appendix III).

Following different sources (Gillett 2009; VNSO 2012; Pascal 2014), it was estimated that more than 5,200 households received some income from commercial fishing activities. This represents more than 10% of households in Vanuatu.

6.2.1.2 QUANTIFY

Reef, nearshore pelagic and deep slope fisheries

The reef and deep slope commercial fisheries are not well developed. They represent, for most households, a complementary and irregular source of income compared to agricultural activities. In villages studied in the north of Efate, less than 5% of the active population (equivalent to 5–10 people) were identified as regular commercial fishers (at least two fishing trips per week) (Pascal 2014). In the villages with the highest proportion of harvest sold (> 60%), fishing activity was predominantly by a small number of very active fishers. Similarly, on Malekula Island the reef fishery was mainly a subsistence fishery, with less than 15% of households (concentrated in 2–3 villages) selling their catches to a wholesaler (usually from the villages) or directly to the market in the capital (Vanuatu Environment Unit 2007; Pascal and Seidl 2013). The 2010 HIES identified that no more than 10% of households were involved in fishing activities that produced cash incomes.

The benefits of small-scale commercial fishing accrue almost entirely to ni-Vanuatu communities, especially rural communities. (© Vatu Molisa)

The three main types of fishing gear employed are gill nets, handlines, deep slope handlines, trolling and spear guns. These types of gear usually target species in families Scaridae, Acanthruridae and Serranidae in the reef fishery, Lutjanidae and Serranidae in deep slope fishing[24] and coastal pelagic species (Scombridae) by trolling.

Commercial catches of finfish and invertebrates are sold fresh or used in food preparation, either as the main dish or as a complement. Commercial fresh or prepared foods are valued using their market prices. The market price per serving of cooked fish (Vt 250–300) is very similar to that for fresh fish per kilogram. The price of reef finfish is species-independent and does not appear to fluctuate widely. The commercial circuit for fresh fish is simple with only one intermediary level. The fishers have two options: sell directly to consumers (in the village or in the city) or to an intermediary who will sell in the city. Sales in the city can be made informally in some neighbourhoods or at the market. Direct sales to businesses such as restaurants or fish retailers were observed only for deep slope catches (mainly lutjanids).

In Efate, sales in villages through local bars (*nakamals*) or shops are increasing and reflect the progressive introduction of a market economy in villages. Prices in the *nakamals* are similar to market prices in the Vila market. In the same way, prepared meals with fish (e.g. *laplap*, rice) are sold in the market.

No recent official statistics of catches are available from the Fisheries Department and local commercial fishers are not obliged to declare their activity. Due to this and the fact that commercial activity is undertaken mostly in an informal and opportunistic manner to cover specific cash needs, special events, etc. (described in Pascal and Seidl 2013) we have chosen to rely mainly on the surveys of the 2010 HIES.

Monthly data on household incomes from fish and seafood sales were converted to annual figures using a correcting factor and catch volumes were estimated using market prices provided by the VNSO. The resulting *value-added* for commercial fishing was then calculated. *Intermediate costs* for commercial fishing represent an average of 21% of the market price[25]. Results are presented in Table 8 and Table 9. However, these data are five years old and catches have recently been slightly higher (G Nimoho, Department of Fisheries, pers. comm.).

TABLE 8 • Volume and value-added of reef, nearshore pelagic and deep sea fisheries in Vanuatu, 2010

	Commercial catch (tonnes)	Annual value-added (US$)	Minimum (US$)	Maximum (US$)
Rural	1600	3,090,000	2,780,000	3,400,000
Urban	120	210,000	190,000	240,000
Total	**1720**	**3,300,000**	**2,970,000**	**3,640,000**

TABLE 9 • Value of main target groups of reef and deep slope fisheries

Target group	Annual value-added (US$)	Proportion of total catch
Fish	2,100,000	64%
Coconut crab	360,000	11%
Crab (including mud crab)[a]	280,000	8%
Lobster	500,000	15%
Other (including prawns)	60,000	2%
Total	**3,300,000**	**100%**

a Data on crabs include land crab

Source: HIES 2010

24 Deep-water snapper fishing activity is currently modest, although it is believed that the fishery has potential for more, but still small-scale, activity. New ice machines have been installed at Lenakel, Tanna, Pamma, Pentecost, Port Olry-Santo and Emae, with plans for more on other islands. To facilitate this initiative, the government has moved to discourage large-scale fishing arrangements inside the country's 12-mile territorial limits to protect local small-scale fishing operations and activities. Deep-water snapper will be one of the main target species for these small-scale fishing activities in the provinces (Friedman et al. 2003).

25 Based on the results described by several authors (Gillett and Lightfoot 2001; Kronen 2003; Kronen 2007).

Distribution of benefits

The benefits of small-scale commercial fishing accrue almost entirely to ni-Vanuatu communities, especially rural communities. The distribution of these benefits across provinces is shown in Table 10.

TABLE 10 • Distribution of value-added of small-scale commercial fisheries by province

Province	Annual value-added (US$)	Proportion of total
Torba	644,000	20%
Sanma	410,000	12%
Penama	429,000	13%
Malampa	857,000	26%
Shefa	158,000	5%
Tafea	802,000	24%
Total	**3,300,000**	**100%**

Source: HIES 2010

More recent information than that presented in Table 10 indicates that the *value-added* of small-scale commercial fisheries now greater for Sanma and less for Torba (G Nimoho, Department of Fisheries, pers. comm.).

Sustainability

Brouard and Grandperrin (1983) compared the yield of the Vanuatu deep slope fishery with the Hawaiian deep slope fishery and made empirical estimates of the potential yield of the Vanuatu fishery based on a number of comparative approaches. Initially, they suggested that the MSY for the deep slope fishery lay between 150 and 380 tonnes per year, but later, citing the Hawaiian fishery, where there was a large unrecorded recreational catch, proposed that the Vanuatu deep slope fishery might yield between 300 to 700 tonnes annually (Dalzell 1990). In 2010, the small-scale commercial fishery caught 1,720 tonnes. However, this estimate included reef, nearshore pelagic and deep slope fish so very little can be said regarding the sustainability of this artisanal fishery.

At best, based on likely sustainable yields for reef fisheries, it is possible that this fishery is sustainable overall but with likely localised depletion (see Section 6.1.5).

Crabs

The main species of crab collected are coconut crabs (*Birugus latro*), white and black crabs (*Cardisoma carnifex* and *C. hirtipes*) and mud crabs (*Scylla serrata*) that are found in the mangroves. The main provinces where crabs are targeted are Torba, Malampa, Penama and Tafea. Coconut crabs come mainly from the Banks and Torres Islands and are destined for the Vila restaurant trade. Past estimates indicated catches up to 20 tonnes per year (Dalzell 1990). The coconut crab has in the past been classified as a vulnerable species by IUCN; it is currently considered data deficient and its status needs review (Eldredge 1996).

Most of the studies on white, black and mud crabs (Hickey 2007; Vanuatu Environment Unit 2007) have focused on Malekula Island (Crab Bay) and Efate Island (Eratap) where large mangrove stands can be found. Crab collection is mainly a subsistence activity (Pascal and Seidl 2013). Approximately 70% of catches are for own consumption, with an average of ten meals per month per household including crab (Pascal and Seidl 2013). Commercial crab sales are very irregular, usually occurring when catches exceed the basic needs of families. It has been estimated that 135,000 to 250,000 crabs[26] were collected every year in Crab Bay (equivalent to 31–57 tonnes per year; Pascal 2014). Nonetheless, even if no household depended on the mud crab (*Scylla serrata*) fishery for more than 30% of its weekly cash needs, a large proportion (60–80%) of the catch in Crab Bay was sold.

26 Based on declared estimated number of fishing trips during crab and non-crab season, average catches per trip and average consumption of crab per week per household.

The HIES 2010 estimates of a crab commercial fishery *value-added*[27] of US$ 640,000 (including both coconut and mud crabs) at national level were compared with results from other more localised studies (Pascal 2014). The *value-added* of commercial sales of crabs from Eratap and Crab Bay (both very important places in Vanuatu for crab collecting) has been estimated at approximately US$ 65,000 in 2012 (Pascal 2014). Considering other potential locations for crab fishing in Vanuatu (Malekula, North Efate, Tabea province and Tafea province) the HIES result is therefore acceptable as a national estimate.

The overall estimate of the value of the commercial crab fishery is higher than previous estimates (such as US$ 540 000 in Gillett 2009). However, Gillett's estimate was based on the HIES 2006 and has not been updated using the HIES 2010. The two HIES surveys followed similar approaches but HIES 2010 addressed some limitations of previous surveys (e.g. improvement of the questionnaire on fish, additional training of interviewers).

Lobster

The lobster fishery[28] is mainly located in Tafea province with some activity in Shefa and Torba provinces. To our knowledge, this fishery has never been described or studied. This fishery probably has limited potential due to the small size of the fringing reef.

Trochus

Trochus (*Trochus niloticus*) and other shellfish[29] that yield substantial quantities of mother-of-pearl are in demand by the fashion and the furniture industries in Asia and Europe. Statistics cited in the Fisheries Department Annual Report (Vanuatu Fisheries Department 2014) indicate that annual exports of processed shells of trochus have fluctuated between 10 and 67 tonnes in the period 2002–2012 (Figure 5).

Trochus and other shellfish are in high demand as these yield substantial quantities of mother-of-pearl. (© Vatu Molisa)

27 Calculations of ***intermediate costs*** are based on Kronen (2003, 2007).

28 Five species of rock lobster are present in Vanuatu, the most important being ***Panulirus penicillatus***.

29 Other shells are harvested, including the green snail (*Turbo mamoratus*), black lip pearl shell (*Pinctada margaritifera*) and big eye (*Turbo* sp.).

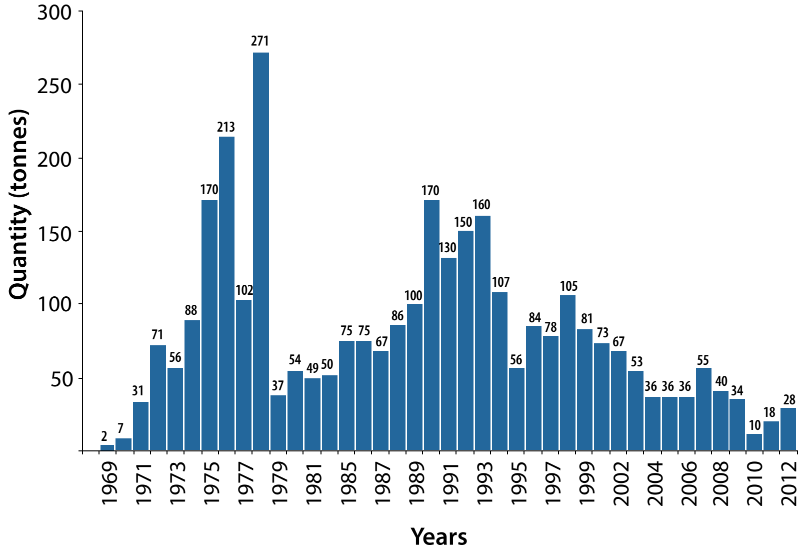

FIGURE 5 • Volume of trochus shell exports, 1969–2012.
Source: Vanuatu Fisheries Department 2014

The value of the 2012 exports reached approximately US$ 170,000[30] generating a *value-added* for Vanuatu of approximately US$ 100,000[31]. Shells are sold to foreign countries in the form of semi-processed shell or as draft converted buttons (Lee and Amos 2001). This shift from the export of low-processed to converted shells is extremely desirable as it produces a higher *value-added* for the raw shells, creating new jobs and stimulating other economic activities in Port Vila (Amos 2007).

Sustainability

The Vanuatu trochus fishery has controls on catches of trochus and many villages have a temporary ban on trochus. Most of these bans were created in response to the severe depletion of trochus stocks in the late 1990s (Johannes 2002). In theory, it was planned to introduce bans every 3–4 years and a limited quota of trochus catch would be given to each household.

Bêche-de-mer

Nine sea cucumber species are the most important commercially harvested species in the *bêche-de-mer* fishery: *Holothuria nobilis*, *H. scabra*, *H. atra*, *Actinopyga miliaris*, *A. echinites*, *A. mauritiana*, *Bohadschia vitiensis*, *Stichopus chloronotus* and *Thelenota ananas*. Little information is available on the species composition of *bêche-de-mer* harvests. The Vanuatu Fisheries Department indicated that for 2004–2005 the main species for export were *A. miliaris*, *B. vitiensis*, *B. argus* and *S. cloronotus*.

An annual quota of 35 tonnes was established by legislation in 1991, and finally implemented in 1996 (Pakoa et al. 2013). Recent stock analysis (P. Dumas, Department of Fisheries, pers. comm.) determined a total volume of 40 tonnes per year as sustainable for future Vanuatu exports. The average annual reported catch of *bêche-de-mer* was 27.4 tonnes from 1997 to 2007 (Figure 6). There was a moratorium on exports 2008–2012. The estimated final market price was US$ 60–85/kg of dried *bêche-de-mer*, equivalent to approximately US$ 3.00–4.75/kg of whole fresh product[32] (Purcell et al. 2012). In 2010, the *free-on-board* price was approximately US$ 2/kg (Purcell et al. 2012). As a result, a broad estimate of US$ 106,000 in *gross revenue*, corresponding to a *value-added*, or *resource rent*, of approximately US$ 51,000 per year for *bêche-de-mer* exports from Vanuatu can be identified.

30 Based on a *free-on-board* price of between US$ 4.6/kg and US$ 8.6/kg, depending on the level of processing of the shells.

31 Based on a level of added value of 60% of sales. This level corresponds to those of the manufacturing sector (Institut des Statistiques Economiques de Nouvelle Calédonie, pers. comm.).

32 Prices are dependent on species and size with dried *Holothuria scabra* reaching prices up to US$ 115–640/kg in markets such as Hong Kong (Purcell et al. 2012).

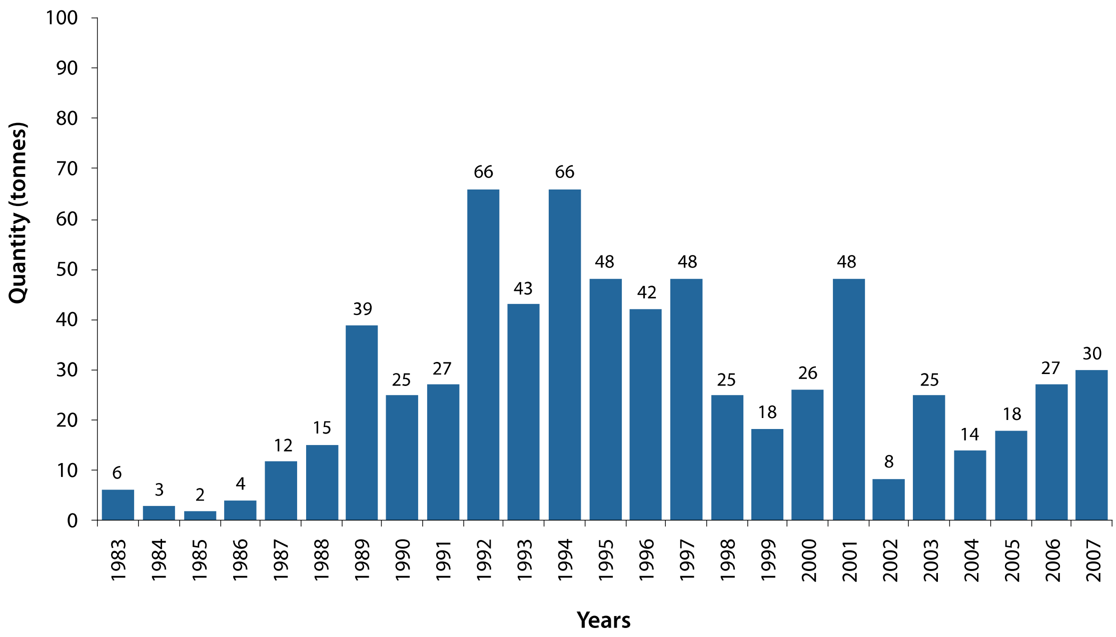

FIGURE 6 • *Bêche-de-mer* exports (tonnes) from Vanuatu, 1983–2007.
Source: Pakoa et al. 2013

Sustainability

Twenty-five years ago, Chambers (1990) recorded a total of 18 species of *bêche-de-mer* from the reefs and seagrass beds of Vanuatu[33]. In most locations, the densities of *bêche-de-mer* were already generally low.

Since then, stocks have been depleted around the more populated areas[34] (Pakoa et al. 2013). Due to concerns about unsustainable harvesting of sea cucumbers a moratorium on fishing was imposed in 2008 for a period of five years finishing in 2012. A recent study based on field surveys has proven that stocks are still overfished (Pakoa et al. 2013). Management recommendations include another five-year moratorium, better enforcement to reduce the illegal fishery, precise price and marketing strategy and an appropriate fishery management plan.

The *bêche-de-mer* fishery was opened in 2013 but no fishing occurred until 2014 when strict and specific quotas and limitations to the geographic extent of the fishery were implemented (G Nimoho, Department of Fisheries, pers. comm.). Catch data for 2014 were not available at the time of writing.

Marine aquarium trade

A small marine aquarium fishery is based on Efate. Ornamental fish is the main product[35], but invertebrates, 'live rocks' (dead coral rock with coralline algae), cultured corals and giant clams are also exported (Vanuatu Fisheries Department 2014).

Marine aquarium product exports were worth approximately US$ 200,000 in export value in 2007 (Vanuatu Fisheries Department 2008). The industry is estimated to contribute about US$ 150,000 to the local economy.

Only three companies are allowed to commercialise and export aquarium products in the country, and a national aquarium fishery management and monitoring plan is being developed.

33 Updated to 23 species by a recent study (Pakoa et al. 2013).

34 Even though some areas under Customary Marine Tenure protect some high-value populations (Hickey 2008). A cooperative management scheme exists in which the Vanuatu Fisheries Division provides scientific information and advice, and coastal villages handle surveillance and local enforcement of the fishery regulations. Today, many villages employ temporal and spatial closures for sea cucumbers.

35 The most traded group are angelfish (family Pomacanthidae) and flame angelfish (*Centropyge loriculus*) is the main species traded.

6.2.2 COMMERCIAL OFFSHORE FISHERIES

6.2.2.1 IDENTIFY

Commercial offshore fisheries include both food and game fisheries. Vanuatu is located south of the tuna hot spots of the Western and Central Pacific Ocean region. There are 175 people employed officially in offshore tuna fisheries in Vanuatu, all on foreign vessels (Vanuatu Fisheries Department and Pacific Islands Forum Fisheries Agency 2014). In 2013, the majority of the foreign long liners licensed by Vanuatu were from China, Fiji and Taiwan.

Vanuatu is a recognised as a blue marlin fishing destination and a range of other game fish are also fished, including fishing on seamounts for wahoo, bait fishing for mahi mahi and jigging for dogtooth. Game fishing companies are mainly based in Efate and Santo close to the main urban centres. In 2013, four companies in Santo (five vessels including a live-aboard) and six companies in Efate (11 vessels) offered game fishing services. Sport fishing charter boats are now categorised as fishing vessels under the revised *Fisheries Act 2014*, meaning game fishing is a licensed fishing activity.

6.2.2.2 QUANTIFY

Tuna fishery

The annual total allowable catch for major tuna species in Vanuatu's EEZ for 2014 was 15,376 tonnes (Vanuatu Fisheries Department and Forum Fisheries Agency 2014). This comprised 8,376 tonnes of albacore (*Thunnus alalunga*), 3,000 tonnes of skipjack (*Katsuwonus pelamis*), 3,000 tonnes of yellowfin (*T. albacares*) and 1,000 tonnes of bigeye (*T. obesus*) (Vanuatu Fisheries Department and Forum Fisheries Agency 2014).

In 2013, 7,558 tonnes were caught in Vanuatu's EEZ (Figure 7) with a total estimated value of US$ 27 million. Albacore and yellowfin were the main species (Oceanic Fisheries Program SPC 2014). The fishery is almost entirely offshore with very few shore-based tuna industry activities[36]. Catches are off-loaded in processing facilities in regional island countries or trans-shipped to distant markets. The benefit of the industry in Vanuatu is therefore mainly from the fees from licensing of foreign fishing vessels. In 2008, US$ 1,360,000 was earned in government *revenue* from fishing vessel licences (FFA 2009). Vanuatu is also party to the multilateral fishing treaty between the United States of America and the FFA member countries, and derives benefits from the treaty funds. Vanuatu receives payments from the Government of the USA and the USA tuna industry for fishing access given to US purse seiners. These payments come under the terms of the US multilateral tuna treaty and represented a value of approximately US$ 250,000 in 2006. Total values outlined in Table 11 below have been adjusted to 2013 figures.

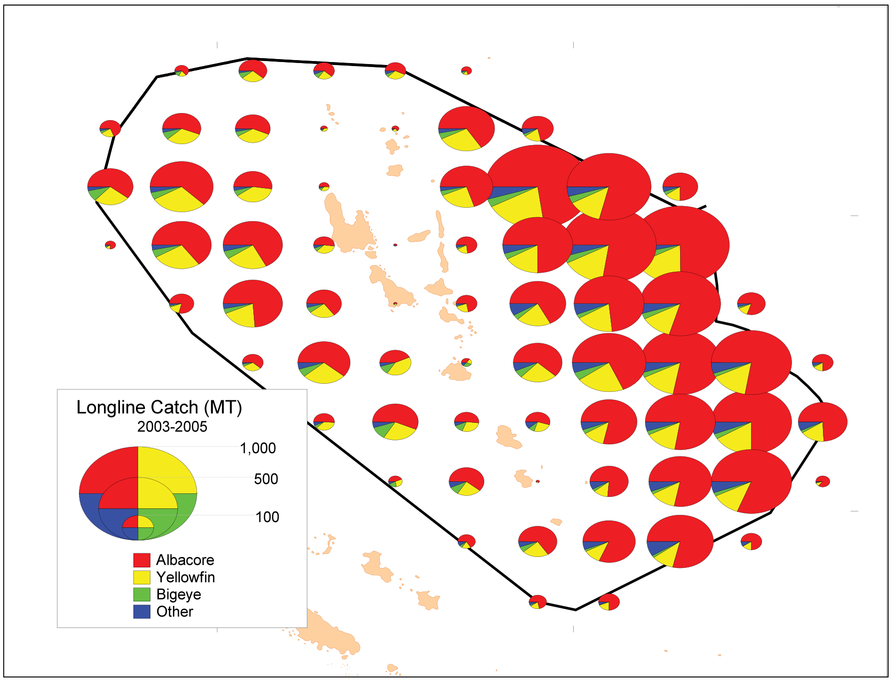

FIGURE 7 • Distribution of tuna catch by species in Vanuatu's EEZ. Source: Vanuatu Fisheries Department and FFA 2014

36 Vanuatu has one company exporting sashimi tuna to Japan (The Tuna Fishing Company) and one failed company which was to launch a processing plant in mid-2009 (Black Sands Fishing Company).

Portions deducted from licences, as well as penalties imposed on vessels for non-compliance, are transferred to the Fisheries Management Fund to be used for management and development of fisheries in the country, particularly in the provinces.

A recent study by the FFA found that if 25% of Vanuatu's catch was brought ashore for processing and shipping, the country could create local business worth US$ 2,500,000 a year, 1,500 new jobs and contribute around US$ 1,500,000 to government *revenue* (FFA 2009). A 2009 report found that the tuna caught in Vanuatu's EEZ is valued at over VT2 billion/year (Gillett 2009).

Game fishery

Prices for rental of a game fishing boat vary from US$ 900 to US$ 1200 per trip (based on four persons for half a day). From interviews with game fishing charter operators conducted in 2012 (Pascal and Seidl 2013), it is estimated that more than 13,000 passengers (mostly non-resident) made a total of approximately 2,900 game fishing trips in 2012. At 20 to 30 kg of fish caught per trip, the total of their catch amounted to approximately 70 tonnes per year[37].

In 2012, the five live-aboard game fishing vessels brought in between US$ 150 and US$ 230 per day per customer and an average *value-added* between 40 and 60% of the turnover[38]. Therefore the total *value-added* of the game fishing sector was around US$ 1,450,000 in 2012. The *value-added* is almost US$ 1,600,000 if the value of the catch is added, measured by the value if they were to be replaced by purchases in the market at a market price of Vt 230/kg.

6.2.3 VALUE OF COMMERCIAL INSHORE AND OFFSHORE FISHERIES

Biomass production of commercial fisheries generated a *value-added* of US$ 7,000,000 for the economy of Vanuatu in 2012 (Table 11). The small-scale commercial fishery (reef fish, nearshore pelagic, deep slope, crabs and lobster) and offshore licensing and game fishing are most important in terms of *value-added*.

6.2.4 UNCERTAINTY

As is common in many developing countries, data regarding small-scale fisheries are highly uncertain (Laurans et al. 2013). Most of the inshore commercial fishing activities are characterised by the same factors as the inshore, subsistence fisheries; they are informal, sporadic and dependent on socio-ecological context. In the same way, they cover a high number of target species (multi-species fishery), fishing gears and habitats. This level of uncertainty is reflected by the range between the minimum and maximum estimates of the valuation (Table 11).

Estimates for pelagic fisheries rely on fishing logs and observers on board and therefore present a higher level of reliability. Data on costs and licences is to be interpreted with caution since, in many cases, they represent only the visible transactions (many agreements are confidential).

In 2014 more than 10 percent of all households received income from commercial fishing activities. (© Vatu Molisa)

37 Based on an average of 180 trips per vessel per year, 4.5 passengers per trip and 20–30 kg of catch per trip.

38 The vessel costs (investment) as well as variable costs (e.g. fuel, gear, maintenance) are high for game fishing activities (IFREMER 2009). Costs are annually amortized on life expectancy of the investments (Kronen 2007).

TABLE 11 • Volume and value-added of commercial fisheries, 2013 adjusted

Fishery	Commercial catch (tonnes)	Annual value-added (US$)	Minimum (US$)	Maximum (US$)
Reef fish, deep slope fish, crabs and lobster	1,720	3,300,000	2,970,000	3,640,000
Trochus and similar	28	100,000	85,000	115,000
Bêche-de-mer	40	50,000	30,000	70,000
Aquarium trading		150,000	90,000	210,000
Offshore fishing	7,558	1,800,000	1,260,000	2,340,000
Game fishing	70	1,600,000	1,360,000	1,840,000
Total	**9,416**	**7,000,000**	**5,795,000**	**8,215,000**

6.3 MINERALS AND AGGREGATE

6.3.1 IDENTIFY

6.3.1.1 DEEP SEA MINING

Deep sea mineral (DSM) exploration in Vanuatu is in its early stages. Three main types of DSM deposits (SMS, manganese nodules, and cobalt-rich crusts (CRCs)) have been discovered in the Vanuatu EEZ and in the seabed beyond national jurisdiction in the last four decades (DGMWR 2014). The mineral deposits considered profitable to mine are mostly SMS. Surveys within the Vanuatu EEZ have found deposits of polymetallic SMS found at sub-sea hydrothermal vent sites which could contain significant quantities of copper, gold, zinc, silver and other commercially valuable minerals.

Mining for manganese nodules and CRCs on the seafloor is likely to have greater environmental impact than mining for SMS. Nodules are small lumpy concretions that form over millions of years as metals from the seawater and seafloor sediments precipitate around a core, which may be a shark tooth or rock fragment. Nodules cover a significant area of the sea floor and contain minerals such as manganese, copper, nickel and cobalt.

The Department of Geology and Mines manages DSM in Vanuatu. A draft Deep Sea Minerals Policy has been developed (DGMWR 2014), and national consultation about the policy will commence soon (as at March 2015).

There are currently 102 active prospecting licences and 44 prospecting licences pending renewal for two prospecting companies. Data about these licences is confidential. Most licences seem to be inactive. Companies from Japan, China, Korea, the UK, Canada, USA, Germany, Australia and the Russian Federation are waiting to see if other prospecting efforts in the region (e.g. Nautilus Solwara in Papua New Guinea[39]) lead to potentially profitable ventures. Bismarck Vanuatu, one of the licensed companies in Vanuatu, commented that at this stage of exploration no potentially commercial deposits have been found.

6.3.1.2 COASTAL AGGREGATE MINING

Some extraction of coastal aggregate (sand, gravel, rock and shell) for construction and reclamation occurs close to Port Vila. The term ‘aggregate’ covers several different types of material that are excavated from the coastline and intertidal flats[40]. Coastal areas are the main source of aggregate for all uses. The principal users are government and the private sector for construction, road building, making cement building blocks, seawall construction and coastal protection and reclamation. In addition, households also use a significant amount of sand and gravel for landscaping.

39 The mining project known as Solwara 1 will extract gold and copper from the floor of the Bismarck Sea in Papua New Guinea. Nautilus Minerals Inc. has secured, or is in the process of applying for, the exploration rights to 534,000 km^2 of the sea floor in PNG, Tonga, the Solomon Islands, Fiji and New Zealand.

40 Aggregate includes sand, composed of fine particles of reef-derived sediment and gravel, defined as reefal sediment of diameter 2 mm to 100 mm. Larger rocks or lumps of cemented reef material are also excavated with individual pieces weighing several hundred kilograms. A limited quantity of shells is also mined from the coastline for specific purposes (Greer Consulting Services 2007).

Sand mining is a practice that extracts sand from an open pit. The sand is often used to make concrete. The management of coastal mining is the responsibility of the Department of Geology and Mines. The department is responsible for issuing development consents for the mining of sand and gravel and for enforcement of the regulations restricting mining to designated areas. Mining is most regulated around the main urban centres where it is officially only permitted from designated sites and requires a mining licence. In 2013, 31 permits were issued. Most licences were issued for construction, and most gravel-mining applicants sell aggregate to builders, construction companies and concrete block makers (Greer Consulting Services 2007).

Hand mining by households is a common practice and can represent ten times the official licensed volumes (Greer Consulting Services 2007). However, extraction of sand by households is illegal and, although it is a benefit obtained by the population, cannot formally be considered as a marine ecosystem service in this study.

6.3.2 QUANTIFY AND VALUE

6.3.2.1 DEEP SEA MINING

No data are available on the benefit that Vanuatu receives from licensing for DSM prospecting because licensing is based on commercial-in-confidence negotiations. Mining does not yet occur in Vanuatu. Very little is known about the potential scale and impacts of DSM. Therefore in terms of data gaps we highlight the need to:

- define sustainable levels of DSM activity
- quantify the potential stock for DSM exploitation
- access global information on licences and exploration potential at national levels.

One of the main difficulties will lie in valuing turnover and *value-added* of the activity. Prospecting activities by definition have highly variable results and economic projections must incorporate this uncertainty.

6.3.2.2 COASTAL AGGREGATE MINING

The official figures from the Department of Geology and Mines are presented in Table 12. Volumes of approximately 15,000 m3 were authorised in 2013, generating 320,000 Vt (US$ 3,600) in fees for the government. It is assumed that illegal extraction of sand takes place in Vanuatu but its volume and value are unknown.

Based on the market price of imports (US$ 90/m3) and a study conducted in Kiribati (Greer Consulting Services 2007), we assumed an average market price of US$ 45 per cubic metre of local sand. The same study has produced a detailed analysis of annual operational costs and initial investments needed for mechanical sand extraction. The percentage *value-added* is estimated to vary between 20% and 30% of the market price (depending on the mining equipment). For 2013, the *value-added* of sand mining for the Vanuatu economy was estimated at approximately US$ 170,000 (15,100,000 Vt).

TABLE 12 • Sand mining permits in Vanuatu, 2010–2013

Year	Total number of permits	Quantity extracted (m^3)
2010	11	3500
2011	14	6700
2012	23	11050
2013	32	15250

Source: Department of Geology and Mines

6.3.3 SUSTAINABILITY

6.3.3.1 DEEP SEA MINING

At this stage of preliminary exploration, there are no indicators for over- or under-exploitation nor is there information about the potential environmental impacts of DSM. Any future economic valuation exercises should include these aspects.

6.3.3.2 COASTAL AGGREGATE MINING

The future demand for aggregate will depend on the level of domestic construction and donor-funded projects. The activity cannot be considered sustainable as long as there remains no strict enforcement of the ban on household sand extraction and no clear regulations (e.g. environmental impact assessment) for private sector licensing. In the absence of sustainable planning, impacts of sand mining can be broadly classified into three categories (Brendan 1992): physical (alteration of channel bed form and shape leads to several impacts such as erosion of channel bed and banks, increase in channel slope, and change in channel morphology); water quality (dumping of overburden, chemical/fuel spills); and ecological (removal of channel substrate, re-suspension of streambed sediment, clearance of vegetation, reduced feeding opportunities).

6.3.4 DISTRIBUTION

The potential beneficiaries from this ecosystem service include the private sector (mining companies and brokers), public institutions and local populations, depending on the terms of the agreement for exploitation and customary rights.

6.4 TOURISM AND RECREATION

6.4.1 IDENTIFY

Marine tourism and recreation activities in Vanuatu include scuba diving, snorkelling, day boat charters, day tours and recreational boating and associated accommodation and other travel costs. In surveys conducted by Pascal and Seidl (2013), Australian citizens represented 70% of respondents, New Caledonian residents 15% and the rest was shared between New Zealand and Europe. There was a clear dominance of resort and hotel users (88% to 94%). Several underlying ecosystem processes have been identified in the provision of marine tourism, such as biomass production, maintenance of habitats and resilience to external pressures (Appendix III).

6.4.2 QUANTIFY

6.4.2.1 PRODUCER SURPLUS OF SERVICE PROVIDERS

Ten dive shops provide services in Vanuatu, of which six are based in Efate (eight boats) and four in Santo (six boats). The dive industry has total capacity of approximately 180 divers per day, with a mean capacity for each operation of 17 divers. The most frequented diving sites are close to the capitals of Efate and Santo (time to access less than 1 hour

Tourism businesses attracting over 70,000 visitors per year depend on the quality of water and beaches.

by boat) and include reefs and wrecks[41]. Some dive shops are based on islands close to the capitals and offer on-site accommodation for divers. Most of the dive companies offer snorkelling activities and technical training courses (Pascal and Seidl 2013).

A total of approximately 47,000 dives were carried out in 2013 corresponding to approximately 9,000 divers. Some 65% of the dives took place in Efate. In addition, 9,000 snorkel trips were documented (Pascal and Seidl 2013). The corresponding *value-added* of the dive shops is estimated at approximately US$ 1,600,000 in 2013 (US$ 1,100,000 in Efate and US$ 500,000 in Santo) (Pascal and Seidl 2013).

The day boat charters in Efate and Santo offer trips of a half or whole day with snorkelling, beach activities and village visits[42]. Boat capacities vary from 6 to 60 guests and vessels range from sailboats to small boutique cruise ships with live-aboard facilities. A total capacity of 250 passengers/day is shared among 16 companies, and some companies are only active for part of the year (from May to December). Other types of day tours are organised overland with tour operators. Three ecotourism operators in Vanuatu offer activities in mangroves in Malekula and Efate. There is an eco-volunteer tourist enterprise in Efate developed through an agreement signed between a village and a UK-based company specialising in this business. It is centred on tourists paying for turtle tagging, monitoring and clinics. They usually stay for long periods (more than 40 nights) (Pascal and Seidl 2013).

Approximately 22,000 visitors enjoy day boat charters annually and another 10,000 participate in day tours with beach, snorkelling or mangrove activities. In 2013, the *value-added* for boat charters and day tours were US$ 1,600,000 and US$ 400,000, respectively. Santo represents US$ 700,000 of the *value-added* of boat charters (Pascal and Seidl 2013).

6.4.2.2 EXPENDITURE OF VISITORS

Average daily expenditure of visitors was estimated at US$ 151 in 2012 for air visitors with an average length of stay of 8 days (equivalent to approximately US$ 1,200 per visitor per stay) by VTO surveys (TRIP Consultants 2008; Pascal 2010; VNSO 2014). Proportions of *value-added* derived from the national GDP calculations (VNSO pers. comm.) and other studies (Pascal 2010; Pascal and Seidl 2013)[43] are applied to this *revenue*[44].

In the surveys by Pascal (2010) and Pascal and Seidl (2013), questions about expenses had a low response rate. The results (n = 67) showed an average expense of US$ 113.50 per day per person. The average length of stay was 7.3 days. Given the size of samples, we chose to rely on estimates from the VTO.

6.4.2.3 ECOSYSTEM CONTRIBUTION FACTOR

The *ecosystem contribution factor* is applied to visitor expenditure to reflect the role of marine and coastal ecosystems in visitors' choice of destination. Visitors were categorised following the criteria set out below. The goal was to divide visitors into homogeneous groups to ensure the most appropriate application of contribution factors. A matrix of variables of marine contribution from the selected surveys, complemented by the analysis of advertising images, was then applied to the expenditure structure of different categories of users or tourists.

The categories of visitors are:

Category I: Visitors (all groups combined) that would not have come to the location were ecosystems not in their current state (*ecosystem contribution factor* = 1). Relevant activities may be specialised diving trips, hunting or underwater photography. Total associated expenditures are accounted for at 100%.

Category II: Visitors who came to the location for several reasons and who participated in activities related to marine ecosystems (see below for the value of the *ecosystem contribution factor*).

Category III: Visitors who did not participate in marine related activities are excluded from this assessment.

41 Including the *SS President Coolidge* publicised as the largest wreck dive in the world.

42 When villages visit are made, a fee (5 to 10% of the total trip price) is paid to community for each visit.

43 Average added values used are: 40–60% for hotels and accommodation, 30–50% for food and beverage and 40–60% for transportation (ISEE 2008).

44 Without concrete details of the distribution of expenses, a usual added value of 50% has been applied to the average expenditure value (Lindberg and Enriquez 1993).

Expenditure of users was calculated using data from the following sources:

a. IUCN-AFD project (Pascal and Seidl 2013) based on surveys (n = 85) with visitors and divers. The respondents were asked to answer specific questions about their choice of destination and the importance of reefs in their choice of destination.

Question 1: What was your main reason for coming to this area?

Question 2: If you had not been able to dive / visit the reef (mangrove), would you have done this trip?

☐ Yes ☐ No ☐ Don't know

Question 3: Diving (/ other activities) has been important in your decision to come to....?

☐ High ☐ Moderate ☐ Low ☐ Don't know

These questions provided information about a variable ecosystem contribution for Category II visitors and users[45]. The study reported that 76% of respondents answered 'yes', 20% 'no' and 4% the 'not sure' box to question 2.

The respondents were mainly beginners in underwater activities; 8% were qualified scuba divers and 23% went snorkelling/diving several times a year.

For the majority of snorkellers (53%), the beauty of the seascapes (e.g. coral reefs, caves) was the most decisive factor for their satisfaction, followed by the diversity and abundance of fish and the quality of the service (e.g. level of organisation, comfort).

b. Pacific Tourism Climate Adaptation Project Visitor Analysis Study (Klint et al. 2012) based on quantitative surveys (n = 199) describing visitors' levels of satisfaction with the experience in Vanuatu and their perceptions, and on qualitative surveys (n = 22) exploring what would represent the ideal day in Vanuatu[46] and the issues that tourists may have had in relation to their travel to Vanuatu.

c. The Vanuatu 2010 VTO exit tourism survey (n = 500) conducted by the VTO in the airport in 2009 determining the characteristics of visitors, their activities and their main motivations.

Studies b. and c. confirmed that the predominant reason visitors chose to holiday in Vanuatu was to relax on the beaches or in the hotels (approximately 90% of respondents). The second reason was to meet new cultures and island living (80%). Observing and discovering nature was identified by 60% of the tourists as an important reason to come to Vanuatu. About 10% of the interviewees responded that snorkelling was a very important reason for their visit.

d. The Analysis of Advertising Images (AIA)[47]

The results from the AIA developed by the IUCN-AFD project (Pascal and Seidl 2013) are used to calculate the contribution of marine ecosystems to tourist motivations. In this study, the types of media employed were quantitatively analysed to determine the proportion of images and keywords related to certain attributes.

The selected attributes were:

- Images related to culture and people
- Images related to terrestrial ecosystems and landscapes
- Images related to beaches
- Images related to recreational underwater coral and marine biodiversity
- Images related to other forms of entertainment

45 The *ecosystem contribution factor* takes the value 1 if the answer to question 2 was 'no'. Otherwise it takes a value between 0 and 1 depending on the proportion of time devoted to marine activities in the duration of the stay, the main motivations for travel and the importance of marine activities in the choice of destination. A matrix of ecosystem contributing factors is generated.

46 It did this through a short writing activity as well as through a drawing activity.

47 This method was first described by Hajkowicz et al. (2005). It is based on tourism advertising media (mainly print and online) seen by tourists before their arrival. The underlying theory is that advertisements are based on a communication strategy. They are designed with a specific target and aim to arouse the recipient's desire to acquire the service promoted. In our case it is used as a proxy for the choice made by tourists in their destination decision.

Some 180 images[48] were classified to determine the importance of the attributes. Marine ecosystem images represented 20% of all the images (Figure 7). They mainly took the form of images of healthy colourful reefs, emblematic species and activities related to the marine environment (game fishing, snorkelling, diving).

The relative number of images containing underwater landscapes or activities is used as a proxy for the role of marine ecosystems in the choice of destination by tourists.

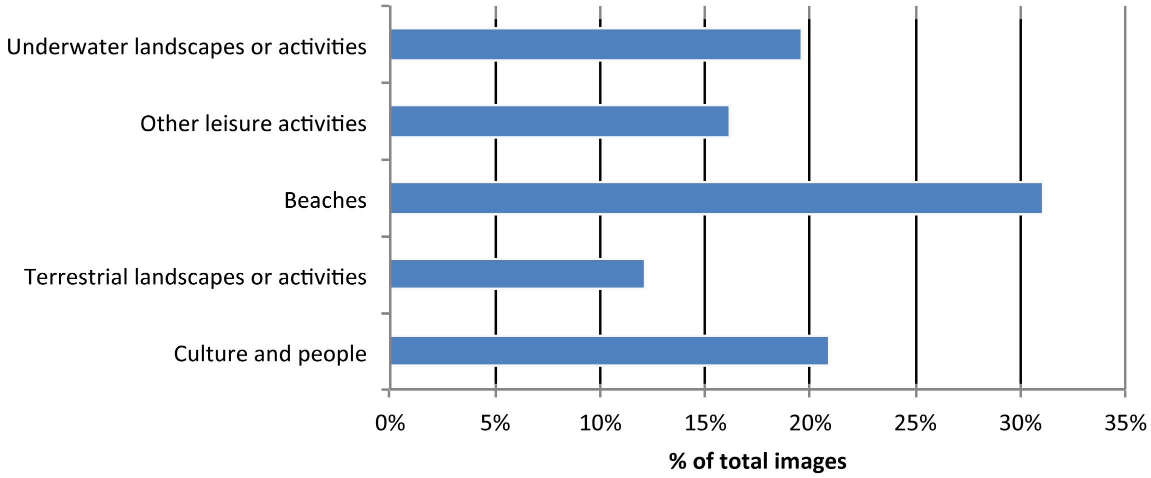

FIGURE 7 • Results from analysis of advertising images for Vanuatu. Source: Pascal and Seidl (2013)

Based on tourism surveys results and advertising image analysis, it was found that 10–20% of divers would not have come to Vanuatu if diving had not been possible (Category I visitors). The *ecosystem contribution factor* applied to expenditures of Category II divers and snorkellers was 55%.

Less than 10% of the day tour and boat charter visitors were classified as Category I and 25–90% were Category II. We applied an *ecosystem contribution factor* of 10–40% to expenses of Category II visitors to reflect that these expenditures could be attributed to the presence of marine ecosystems (an average *ecosystem contribution factor* of 25%). Visitors on live-aboard boats (two cruise companies) were categorised as Category I to reflect that all their expenses are linked to marine ecosystems.

Cruise tourists

Cruise lines have a structure of expenditure and incentives that is very different from other tourist expenditure and have thus been treated separately. Most cruise tourists come for a very short time (usually less than a day) to shop and take a dive or day tour with a tour operator (VTO 2009). Their associated expenses are very limited because of the short duration and because of brokerage agreements between the cruise operators and local tourism (high *intermediate costs*) (A. Seidl, pers. comm.). For that reason, we considered only the budget spent by cruise tourists on diving and day tours but did not include any value for their other expenses.

Resident users

Local residents who participate in reef or mangrove activities may also incur accommodation expenses, meals and transportation that must be taken into account. These residents are based mainly in Port Vila and might spend holidays and weekends in remote places in the north of Efate. Relying on the results of Pascal and Seidl (2013), which focused on this area, we found that approximately every year, 4,000 local visitors were hosted in guesthouses and the resorts in the north of Efate. Average length of stay was two nights with average expenditure of US$ 40 per night per person. Based on the same surveys, 2,100 of these visitors took part in snorkelling activities. Some 5–10% of the visitors were classified as Category I and 30–65% of them as Category II. The total *value-added* was less than US$ 150,000 per year.

48 These images were available to tourists before their arrival or before they realised the activities/visit and were from different Sources: official VTO website and links to private businesses; private web pages of main tourism operators, cruise operators, scuba diving operators, yacht charterers and hotels/resorts; specialised webpages for scuba diving and free diving; specialised webpages for tourism (backpackers, nature destinations, etc.); and brochures found in airports, hotels, travel agents and dive shops.

6.4.3 VALUE

A total of 56,100 users (visitors and residents) participated in different tourism and recreational activities related to the marine environment (Table 13). The total estimated *value-added* for tourism and recreation in Vanuatu was US$ 9,590,000 but had a wide range (Table 14).

TABLE 13 • Visitors to Vanuatu by category of intensity of use

	Number of visitors	Category I*	Category II**	Ecosystem contribution factora
Scuba divers and snorkellers (on-board)	9,000	10–20%	80–90%	55%
Boat charters	22,000	5–10%	30–80%	25%
Day tours	10,000	0–5%	25–90%	25%
Game fishers	13,000			
Residents (using accommodation)	2,100	5–10%	30–65%	55%

a *Ecosystem contribution factor* is expressed as a proportion of total associated expenses of Category II tourists in the country
* Category I: Visitors that would not have come to the location were ecosystems not in their current state
**Category II: Visitors who came to the location for several reasons and who participated in activities related to marine ecosystems

TABLE 14 • Value-added for tourism in Vanuatu, 2013

	Annual value-added (US$)	Minimum (US$)	Maximum (US$)
Scuba divers and snorkellers (on-board)	5,050,000	3,535,000	6,565,000
Boat charters	3,380,000	2,540,000	4,230,000
Day tours	1,160,000	810,000	1,510,000
Total	**9,590,000**	**6,885,000**	**12,305,000**

6.4.4 SUSTAINABILITY

Vanuatu has relatively low visitation rates with a low risk of exceeding the capacity of the reef compared with other destinations (Hawkins and Roberts 1992; Scura and van't Hof 1993; Davis and Tisdell 1996; Harriott et al. 1997; Barker and Roberts 2004; Hasler and Ott 2008; Uyarra et al. 2008). We assume therefore that the *economic value* obtained for this ecosystem service can be sustained.

6.4.5 UNCERTAINTY

The main uncertainty lies in the estimates of the *ecosystem contribution factor*. It is perhaps obvious that no one would travel to Vanuatu were it not for the abundant marine resources. However, the availability of close substitutes for beaches and reefs in the region work to reduce the relative value of these resources to potential visitors. The approach of estimating this factor through different methods and comparing several sources of estimates is a way to reduce this uncertainty. Nonetheless, uncertainty remains, as user dependency on marine ecosystems is a parameter that requires quantitative approaches with extensive surveys, which were not available for this study.

6.4.6 DISTRIBUTION

We identified 50 tourism businesses supporting over 56,000 users per year as the main beneficiaries of tourism and recreation in Vanuatu. The businesses provide some benefits to Vanuatu, the degree depending on whether the businesses are local- or foreign-owned. Most users of marine tourism and recreation are visitors so the consumer benefits largely accrue outside the country.

The aggregated results for the ecosystem service of tourism and recreation are presented in Table 15. The total *value-added* was approximately US$ 9,500,000 in 2013. Diving and snorkelling represented more than 50% of the average value.

TABLE 15 • Value-added of tourism and recreation by province and tourism sector, 2013

	Efate (% total *value-added*)	Santo (% total *value-added*)	Annual *value-added* (US$)	Minimum (US$)	Maximum (US$)
Scuba divers and snorkellers (on-board)	66	34	5,050,000	3,535,000	6,565,000
Boat charters	75	25	3,380,000	2,540,000	4,230,000
Day tours	68	32	1,160,000	810,000	1,510,000
Total	**69**	**31**	**9,590,000**	**6,885,000**	**12,305,000**

6.5 COASTAL PROTECTION

This section on coastal protection was summarised from Pascal (2015), a report exploring the coastal protection ecosystem service in all five MACBIO countries and prepared for the MACBIO project. For more details on the methods or results, refer to Pascal (2015).

6.5.1 IDENTIFY

Coastal protection describes the different roles that ecosystems can play in protecting people, assets and infrastructure from wave and storm damage. The two main roles identified and described here are:

- prevention of erosion, sediment provision and/or accretion
- mitigation of storm surges.

The 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), while 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.

6.5.1.1 EROSION PREVENTION AND SEDIMENT PROVISION

Coastal ecosystems in Vanuatu play an important role in stabilisation of shorelines. The increase in human density along the coast and the resultant increasing pressure on coastal ecosystems lead to a paradox: an increase in the need for stabilised shorelines, but a decline in natural stabilising processes.

The role of mangroves in coastal stabilisation is well known (Marchand et al. 2011; Bell and Lovelock 2013). Sediment processes protect coastal soil from erosion, and in some cases permit reinforcement of shoreline materials. In the same way, seagrasses form extensive meadows in the coastal areas they colonise. Their roots and rhizomes fix the material in which they grow and their leaves slow currents, thus enhancing the stability of their sedimentary substrates. This action dissipates wave energy (up to 40% of erosive energy when seagrasses are dense; Barbier et al. 2011) and also increases the rate of sedimentation (Pearson 2001). As such, seagrass beds effectively contribute to protection against waves and limit coastal erosion.

In addition, reefs are known to participate in 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, to quantify and value those with readily available data. Many authors agree that the 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 1 km 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, two major aspects have been identified for Vanuatu:

i. stabilisation of shorelines, critical in high human density sites (e.g. Port Vila)

ii. beach formation and stabilisation, important in tourist areas.

In Vanuatu, the sedimentation processes in Port Vila Bay, where both residential and tourism infrastructure assets are concentrated, appear to be important.

The role of coral reefs in erosion protection processes (sedimentation and accretion) is less well understood than the role of mangroves. Furthermore, although some natural processes involved in erosion protection are well described, it is still difficult to precisely quantify and estimate the *economic value* of such processes.

6.5.1.2 STORM SURGE MITIGATION

This report focuses mainly on the value of storm surge mitigation by coral reefs, which is one of the most important aspects of coastal protection provided by marine ecosystems (Laurans et al. 2013). As a point of reference, the average annual direct loss caused by 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 destruction of cash crops and 10% from damage to built 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[49]. Storm surges can interact with other ocean processes such as tides and waves to further increase coastal sea levels and flooding, and will 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 inundation and 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)[50].

The coastal bathymetry (the shape and depth of sea or ocean floor), 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, seagrass and mangroves 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 and 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 and mangroves in coastal protection is difficult to isolate from other variables and, in fact, a combination of factors impact on the level of protection provided. The primary factors influencing attenuation of wave energy are:

i. bathymetry (shape and depth of sea or ocean floor)

ii. geomorphology (soil origin, size and composition)

iii. topography (coastal and inland surface shape, as well as shoreline indentations)

iv. biological cover (presence of other ecosystems in the coastal area) (Burke 2004).

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

50 A tsunami wave differs from 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 case of tsunami waves, due to this vertical distribution of energy throughout the column water rather than a surface distribution for storm surge waves.

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 energy was nonlinear. Similar nonlinear effects have been measured for the effect of mangroves on wave height. Waves of 1.1 m in the sea are reduced to 0.91 m in the mangrove forest if the forest has an inland extension of 100 m. The wave continues to decline, at a slower rate, for each additional 100 m of mangroves extension inland. For a forest extending 1000 m inland, the waves would be reduced to a negligible 0.12 m[51] (Barbier et al. 2008).

6.5.2 QUANTIFY

6.5.2.1 COASTAL PROTECTION INDEX

Two methods can be used to assess the role of coral reefs[52] 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 for small study areas, we chose to use a physical and mechanical model for our evaluation. One of the main limitations of such models is that we were not able to assess the true relationship between coral mortality and its role in loss of the coastal protection service.

The model used for this study scores coastal stability based on seven physical characteristics (Table 16). These physical characteristics were given a score between 1 and 5 and the average was calculated to produce a unique index value for each segment of shoreline: the coastal protection index.

TABLE 16 • Calculation of the coastal protection index based on characteristics of the coastline

Factor	Score				
	Very strong	Strong	Medium	Low	Null
	5	4	3	2	1
Geomorphology	Rocky shore	Mix of rocks/ sediments/ mangroves	Mangroves	Sediments	Beaches
Coastal exposure	Protected bay	Semi-protected bays	Artificial reefs	Low protected bay or coast	No protection
Reef morphology, area and distance to coastal physical structure	Continuous barrier (> 80%) close to the coast (< 1 km)	Continuous barrier (> 50%), patch reef, close to the reef	Fringing reef (width > 100 m)	Coral formation discontinuous	No reef
Inner slope, crest width	Very favourable conditions (gentle slope, large crest width)	Favourable conditions (slope, large crest width)	Favourable conditions (at least one condition: slope, crest width)	Reduced favourable conditions (strong slope, reduced crest width)	None
Platform slope	6–10%	2.5–6%	1.1–2.5%	0.4–1.1%	< 0.4%
Mean depth (< 1 km from the shoreline)	< 2 m	< 5 m	> 5 m	< 10 m	< 30 m
Other ecosystems	Mangroves and seagrasses > 75% coastline	Mangroves and seagrasses > 50% coastline	Mangroves and seagrasses > 25% coastline	Mangroves and seagrasses < 25% coastline	None

51 In addition, some studies have shown that the extent of reefs or mangrove may not be the main factor influencing the reduction of damage on the coast from tsunamis (Done et al. 1996; Greer Consulting Services 2007; Pérez-Maqueo et al. 2007).

52 Three major ecosystems contribute to coastal protection: coral reefs, mangroves and seagrasses. Nonetheless methodologies to assess ***economic impacts*** of mangroves and seagrass in terms of coastal protection are not yet consolidated (Huang et al. 2007; Pérez-Maqueo et al. 2007; IFRECOR 2011; Pascal 2013), the specific role of those ecosystems is not monetarised in the present study; they are only used in the coastal protection index as some of the main factors contributing to coastal protection.

Two main GIS databases were used for data related to reefs (i.e. type of reefs, area and distance to the coast): PCRAFI and Reefbase data.

The three most inhabited islands in Vanuatu are valued in this study: Efate (the main island, including the capital city, Port Vila), Espiritu Santo and Malekula. Based on coral reef morphology and coastal exposure variables, Efate was divided into two segments (west and east). The majority of the population is located on the west shore. The other two islands were not divided, but studied as entire areas.

Geomorphology: The shoreline soil of these islands is of sedimentary origin. Mangroves are present at some locations but they are not sufficiently viable to take into account for scoring for this factor. The score for geomorphology for Vanuatu is low (2).

Coastal exposure: On the west coast of Efate, the city of Port Vila is located around Mele Bay. The factor coastal exposure is at a maximum for the city of Port Vila. For the entire study area, as this bay is the only one of the shoreline, the factor coastal exposure is strong (4). The factor is null on the east side, due to the lack of any specific geographic features of the coast protecting assets.

On Espiritu Santo, while the presence of a huge bay in the north, Big Bay, reinforces the factor for the whole island, few people live along the shoreline protected by the bay (population is concentrated mainly in the south of the island). As a result, the score for coastal exposure for Espiritu Santo is medium (3).

There is a small bay (Umbeb Bay) in the south of Malekula but the shoreline is generally linear. The score for coastal exposure for Malekula is low (2).

Reef morphology, area and distance to the coast: The islands are surrounded by fringing reefs, which are almost continuous in Efate, but less developed on the other two islands. However, the same score was assigned to all islands, as all of the most populated areas of these islands have fringing reefs fronting them. The reef morphology, area and distance to the coast score is medium (3) for the three islands.

Inner slope, crest width: The reef crest is relatively narrow (10–25 m), while the inner slope is medium or absent. In every study area, the score for inner slope, crest width is medium (3).

Platform slope: The deep ocean is near the shoreline of these three islands, so the platform presents an important slope. Although the islands are close to each other and the ocean between them is not at its deepest the platform still has an important slope. The platform slope score is strong (4) for all islands.

Main depth (1 km from the shoreline): The deep ocean is near the shoreline for the three islands with the main depth greater than 30 metres less than 1 km from the coast. The score for main depth is null (1) everywhere.

Other ecosystems: Mangroves are present in Vanuatu. However, official data with the precise location of mangroves along the shoreline could not be obtained. Based on estimates, the score for other ecosystems is medium (3) in Vanuatu.

The scores are summarised in Table 17.

TABLE 17 • Coastal protection index scores for four study areas in Vanuatu (on islands of Efate, Malekula and Espiritu Santo)

Factor	West coast Efate	East coast Efate	Malekula	Espiritu Santo
Geomorphology	2	2	2	2
Coastal exposure	4	1	2	3
Reef morphology, area and distance to the coast	3	3	3	2
Inner slope, crest width	3	3	3	3
Platform slope	4	4	4	4
Main depth (1 km from the shoreline)	1	1	1	1
Other ecosystems	3	3	3	3
Average	**3**	**2**	**3**	**3**

6.5.2.2 MAIN NOTABLE ASSETS AT RISK

We assessed the number, type and location of residential buildings and hotels at risk from coastal flooding and tsunamis. No robust information related to other construction works, such as public buildings and infrastructure (e.g. roads, bridges and airports) was available. Agricultural crops were also not included in the study, due to the absence of intensive crop production in the areas at risk. Data on indirect tangible damage (e.g. loss of tourism *revenue*, emergency costs, traffic disruption) were also unavailable.

Main cities: the two main cities of the country are Port Vila, the administrative and economic capital of the country located on the southwest coast of Efate, and Luganville on the southeast coast of Espiritu Santo. Most of the hotels and the population of each island are located around those two cities.

Tourism: most tourism is concentrated in Espiritu Santo and Efate. The location of luxury hotels on each island identifies the principal tourism areas (Table 18).

On Espiritu Santo, the seven hotels of greater than three stars are concentrated around Luganville, not far from the airport. There is a relatively high proportion of private island resorts (three of a total of seven), located on small islands and islets to the south of Luganville. In Espiritu Santo there are also a relatively large number of secondary hotels and vacation residences (six un-starred hotels, ten bed-and-breakfasts, eight other vacation residences).

On Efate, the 28 hotels of greater than two stars are primarily located in the south-west, from east of Teouma Bay to the north-western extremity of Mele Bay. Most are concentrated in Port Vila in Vila Bay, on the strip of land between Vila Bay in the west and the Erakor Lagoon to the east. Note the absence of five star hotels on the island.

TABLE 18 • Hotels on Efate and Espiritu Santo

Type of vacation residence	Efate	Espiritu Santo
5-star hotel	0	1
4-star hotel	8	1
3-star hotel	19	5
2-star hotel	1	0
Other hotel	15	6
Other type of tourist residence	46	18
TOTAL	**89**	**31**

6.5.3 VALUE

The method used to value the service of protection against storm damage by coral reefs[53] is the *avoided damage cost method*. First the assets protected are identified and quantified. Then, the *ecosystem contribution factor* of coral reef and associated systems is applied. Finally, the ecosystem service is valued in terms of the cost of damage avoided. One of the main challenges of this method is that coastal protection against waves is a complex process, incorporating many factors such as geomorphology of the coast and the presence of other ecosystems. The identification of the contributing role of each of the different factors is a challenging task and is outside the scope of this study. For more details on methods, see Pascal (2015).

Similar methodologies used to value this ecosystem service have been tested on Caribbean (Burke 2004) and New Caledonian reefs (Pascal 2010).

The total cost of avoided damage and annual avoided damage due to the presence of reefs on human assets at risk are presented for the four studied areas in Table 19–22. Consolidated results for the three islands are shown in Table 23.

53 Methods to assess ***economic value*** of mangroves and seagrass for coastal protection are not yet implemented (Huang et al. 2007; Pérez-Maqueo et al. 2007; IFRECOR 2011; Pascal 2013) and the specific role of those ecosystems was used mainly for calculation of the coastal protection index as one of the main factors contributing to coastal protection. Their role has not been monetised in this study.

TABLE 19 • Cost of damage avoided due to the presence of coral reefs, west coast of Efate

Coastal protection index	0.25	Number		Unit	Currency	Total value of avoided damage		Annual value of avoided damage	
Extreme climatic event probability	0.42	Min	Max			Minimum	Maximum	Minimum	Maximum
Houses		1188	1980	Houses	US$	14,531,224	24,218,706	6,103,114	10,171,857
					Vt	1,293,278,936	2,155,464,834	543,177,146	905,295,273
Luxury hotel		17	29	Hotels	US$	5,465,777	9,109,628	2,295,626	3,826,044
					Vt	486,454,153	810,756,892	204,310,714	340,517,916
Total					US$	19,997,001	33,328,335	8,398,740	13,997,901
					Vt	1,779,733,089	2,966,221,815	747,487,860	1,245,813,189

TABLE 20 • Cost of damage avoided due to the presence of coral reefs, east coast of Efate

Coastal protection index	0.28	Number		Unit	Currency	Total value of avoided damage		Annual value of avoided damage	
Extreme climatic event probability	0.42	Min	Max			Minimum	Maximum	Minimum	Maximum
Houses		1188	1980	Houses Vt	US$	1,694,698	2,824,496	711,773	1,186,289
					Vt	150,828,122	251,380,144	63,347,797	105,579,721
Luxury hotel		17	29	Hotels	US$	126,019	210,031	52,928	88,213
					Vt	11,215,691	18,692,759	4,710,592	7,850,957
Total					US$	1,820,717	3,034,528	764,701	1,274,502
					Vt	162,043,813	270,072,992	68,058,389	113,430,678

TABLE 21 • Cost of damage avoided due to the presence of coral reefs, Malekula

Coastal protection index	0.23	Number		Unit	Currency	Total value of avoided damage		Annual value of avoided damage	
Extreme climatic event probability	0.42	Min	Max			Minimum	Maximum	Minimum	Maximum
Houses		1188	1980	Houses	US$	1,865,941	3,109,902	783,965	1,306,159
					Vt	166,068,749	276,781,278	69,772,885	116,248,151
Total					US$	1,865,941	3,109,902	783,695	1,306,159
					Vt	166,068,749	276,781,278	69,772,885	116,248,151

TABLE 22 • Cost of damage avoided due to the presence of coral reefs, Espiritu Santo

Coastal protection index	0.23	Number		Unit	Currency	Total value of avoided damage		Annual value of avoided damage	
Extreme climatic event probability	0.42	Min	Max			Minimum	Maximum	Minimum	Maximum
Houses		1188	1980	Houses	US$	6,043,668	10,072,780	2,538,341	4,230,568
					Vt	537,886,452	896,477,420	225,912,349	376,520,552
Luxury hotel		17	29	Hotels	US$	860,937	1,434,895	361,594	602,656
					Vt	76,623,393	127,705,655	32,181,866	53,636,384
Total					US$	6,904,605	11,507,675	2,899,934	4,833,224
					Vt	614,509,845	1,024,183,075	258,094,126	430,156,936

TABLE 23 • Cost of damage avoided due to the presence of coral reefs, consolidated across Efate, Malekula and Espiritu Santo

Coastal protection index	0.25	Number		Unit	Currency	Total value of avoided damage		Annual value of avoided damage	
Extreme climatic event probability	0.42	Min	Max			Minimum	Maximum	Minimum	Maximum
Houses		1188	1980	Houses	US$	26,347,400	43,912,333	11,065,908	18,443,180
					Vt	2,344,918,600	3,908,197,637	984,865,812	1,641,443,020
Luxury hotel		17	29	Hotels	US$	6,452,733	10,754,555	2,710,148	4,516,913
					Vt	574,293,237	957,155,395	241,203,172	402,005,257
Total					US$	32,800,132	54,666,887	13,776,056	22,960,093
					Vt	2,919,211,748	4,865,352,943	1,226,068,984	2,043,448,277

The coastal protection provided by coral reefs is important for hotels in two areas: on Espiritu Santo around Luganville and the small southern and south-eastern islands (Aore, Tutuba, Malo, Aese); and on Efate in Port Vila, where there are 28 hotels (except for one located on the northern shoreline in front of Tranquility Island). Furthermore, those areas where hotels seem to be concentrated are also the areas where the population density is the highest, and where most public infrastructure occurs (e.g. airports, roads — not evaluated here due to lack of knowledge about construction costs). It appears that south-east Espiritu Santo and south-west Efate concentrate an important share of all human assets at risk of Vanuatu.

6.5.4 UNCERTAINTY

This approach is exploratory. It aims to produce an overview of the quantification and valuation of coastal protection provided by coral reefs against flooding caused by storm surges. Many uncertainties are present in every step of the analysis. The main sources of uncertainty are the choice of damage functions (flood damage percentage), definition of zones at risk, the data used for GIS analysis, the database of assets and valuations of construction costs. For details, see Pascal (2015).

Our approach to defining zones at risk partly consists of counting assets at risk from satellite images, which is likely to lead to underestimates. The damage costs of flooding are therefore likely to be higher.

A standard construction cost was used across the five MACBIO countries, regardless of the type of structure and materials. Even if this standard reflects an average construction price per square metre, it is likely to underestimate the total repair cost of assets at risk.

The flood damage percentage used in the analysis came from estimates made by the US Federal Emergency Management Agency for houses in California. Houses in Vanuatu may suffer higher rates of damage since they are generally of lower construction quality. Again, this suggests that actual damage costs may be higher than estimated.

Minimum and maximum values are presented in Table 19–23 to reflect these uncertainties. The minimum number of houses in areas at risk was calculated by multiplying the estimated total number of houses by a factor of 0.75, while the maximum value was calculated by multiplying the total number of houses by a factor of 1.25.

This analysis provides an overview of the role of coral reefs in protection of some built assets (residences and hotels) at risk of extreme climatic events. Many additional parameters must be taken into account to better understand the link between coastal habitats and coastal protection. The role of seagrasses, live coral cover and processes involved in erosion regulation, and impacts on other built infrastructure and crops also need to be explored to fully value this ecosystem service.

The predicted rise of extreme climatic events due to global warming will increase the annual cost of damage to coastal areas.

6.5.5 SUSTAINABILITY

Reef, mangrove, and seagrass ecosystems provide consistent coastal protection benefits indefinitely, as long as the ecosystems remain intact. Damage to reefs and mangroves from coastal development is an ongoing threat (Burke et al. 2008). The magnitude of the services could be increased in some instances by restoring blighted or damaged reefs, mangroves and seagrasses.

Climate change, in particular acidification of oceans and warmer water temperatures, could impact reefs and mangroves and threaten the sustainability of this ecosystem service. Climate change may also increase the intensity and severity of storms, increasing the importance of coastal protection services but also increasing the expected damage. Cyclone Pam demonstrated in Vanuatu that the most severe storms will cause catastrophic flooding and erosion. It is difficult to estimate how much damage would have occurred in Vanuatu if it were not for the presence of living reef and mangrove ecosystems.

6.5.6 DISTRIBUTION

The benefits of coastal protection accrue to anyone who owns or uses 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 decrease the country's tax burden through avoided repair costs.

6.6 CARBON SEQUESTRATION

6.6.1 IDENTIFY

Seagrass and mangrove ecosystems remove carbon dioxide (CO_2) from the atmosphere via photosynthesis, return some to the atmosphere through respiration and oxidation and store the remainder in two stocks: living biomass (which includes both above- and below-ground vegetation); and soil organic carbon (Knowlton 2000; Walters et al. 2008). The rate of carbon sequestration quantifies the carbon added to biomass and soil carbon pools each year. For intact ecosystems, mature vegetation maintains a constant live biomass and the soil stock accounts for almost all sequestration. The carbon sequestration rate is assumed to be constant over time (Jennerjahn and Ittekkot 2002; Suzuki and Kawahata 2004; Duarte and Middleburg 2005).

The following analysis is based also on the MESCAL economic analysis of mangrove ecosystem services in Vanuatu (Pascal 2014). A detailed description of the method is given in Appendix IV and in Salcone et al. (2015).

6.6.2 QUANTIFY

The average ranges of carbon sequestration were estimated based on recent publications (Jennerjahn and Ittekkot 2002; Bouillon et al. 2009). Sequestration rates vary for mangroves from 0.1 to 24 tonnes CO_2-equivalent per hectare per year ($tCO_2eq/ha/yr$) and for seagrass from -9.4 tonnes to 50.22 $tCO_2eq/ha/yr$. Global average sequestration rates for mangroves and seagrasses are 6.32 $tCO_2eq/ha/yr$ and 4.4 $tCO_2eq/ha/yr$, respectively (Murray et al. 2010). Only 5% of the carbon is stored in living biomass in seagrass and between 20% and 40% in mangroves. Soil carbon is the main carbon stock, with a maximum of 500 tCO_2eq/ha for seagrasses and approximately 1,900 tCO_2eq/ha for mangroves (Figure 8; Murray et al. 2010).

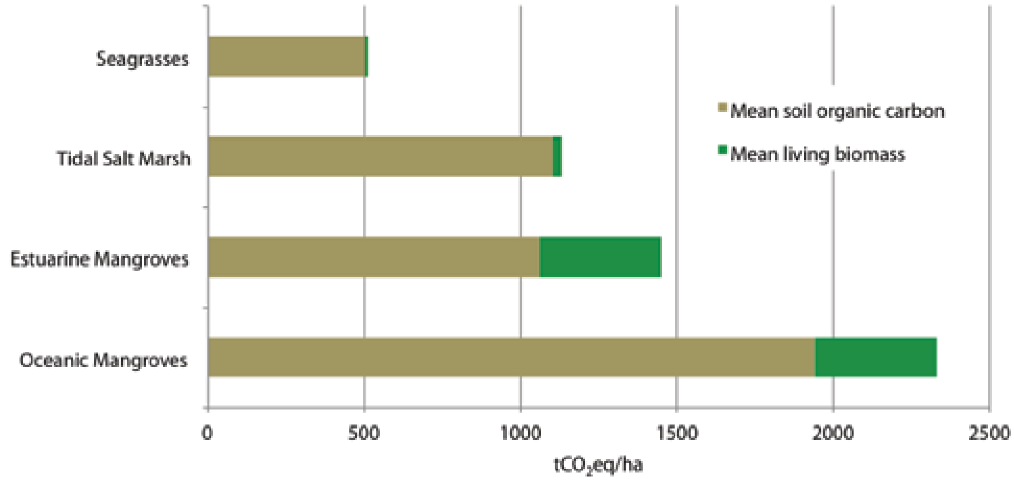

FIGURE 8 • Global averages of above- and below-ground carbon pools of marine and coastal ecosystems. Source: Sifleet et al. (2011)

Mangrove carbon pools are among the highest per hectare of any forest type (Figure 9). For example, mangrove ecosystem carbon pools are more than twice those of most upland tropical and temperate forests. A great proportion of this pool is below ground in organic-rich soils that can release significant volumes of greenhouse gases if disturbed by land use or climate change (Kauffman and Donato 2012).

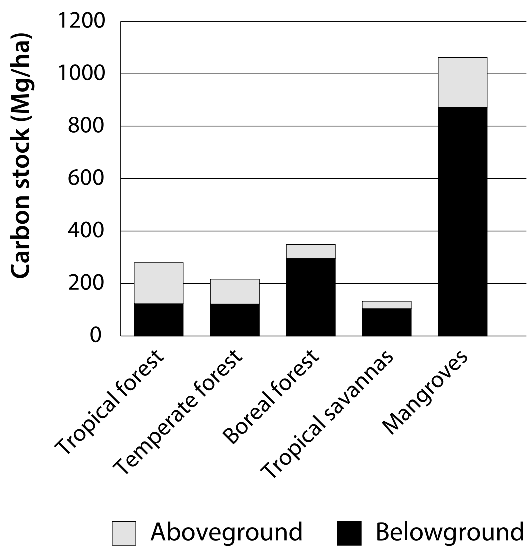

FIGURE 9 • Total ecosystem carbon pools for some major land cover types. Source: Kauffman and Donato (2012)

We use two approaches to value carbon sequestration by marine and coastal ecosystems. The first is based on the social cost of carbon and reflects the amount of carbon sequestered every year by mangroves and seagrass. The second calculates the value of the annual amount of CO_2 equivalent not released into the atmosphere by maintaining ecosystems in their current state, based on the market price of carbon. For this approach, the parameters estimated are:

- annual rate of absorption of carbon by the ecosystem in its current state
- carbon stocks in biomass and in the ground (up to a maximum depth of 1 m)[54]. For Vanuatu, the data are based on estimates of the International Panel on Climate Change (IPCC) tier 1 category[55]
- the amount of potential emissions due to the destruction of the ecosystems. This evaluates how much soil carbon may potentially be exposed to oxygen and thereby released as CO_2. Although metres of carbon-rich organic soils may underlie coastal habitats, that carbon may persist if the habitat conversion only affects the top layers and the deeper layers remain inundated
- the time required for the release into the atmosphere of emissions. In theory, carbon in biomass is emitted to the atmosphere in the first few years following conversion from mangrove forest to non-mangrove forest. Soil organic carbon will take longer than biomass and the deeper the soil carbon the slower its rate of release. In each case, high emission rates would be expected in the years immediately after disturbance, dropping to lower rates later. A decay function may approximate this physical process, especially using the concept of half-life that denotes the time required for the carbon pool to fall to one half of its initial value[56]. Scientific understanding of post-conversion rates of CO_2 emissions is currently embryonic; accordingly, we make conservative assumptions.

We estimated a rate of deforestation between 0.1% and 0.2% of the total surface area of mangroves per year. This ratio is based on expert opinion and analysis of the existing literature about mangroves in Crab Bay and Eratap (Vanuatu Environment Unit 2007). It reflects relatively low pressure on mangroves as well as efficient management of habitat (Pascal 2014). See Appendix IV for more details.

6.6.3 VALUE

6.6.3.1 SOCIAL CARBON PRICE

The total area of mangroves in Vanuatu was recently estimated at 2,700 hectares and seagrass covered 1,500 hectares (Laffoley 2013). Using global average rates of sequestration, Vanuatu mangroves sequester approximately 17,000 tonnes of CO_2 per year, and seagrasses about 6,600 tCO_2/yr, worth approximately US$ 1.4 million per year (Table 24). The value of this service is calculated based on the social cost of carbon of US$ 61 per tonne per year (US EPA 2014). Note that if the minimum sequestration rate is negative (that is, the habitat is producing CO_2) we set it to zero in the final valuation (see Appendix IV).

TABLE 24 • Social value of carbon sequestration by mangroves and seagrass in Vanuatu

Habitat	Habitat area (ha)	Volume of carbon sequestered (tCO_2eq/yr)			Value of social carbon (US$/yr)		
		Min	Max	Mean	Min	Max	Mean
Mangrove	2,700	324	64,800	17,064	19,764	3,952,800	1,040,904
Seagrass	1,500	-14,100	75,330	6,600	0	4,595,130	402,600
Total		**-13,776**	**140,130**	**23,664**	**19,764**	**8,547,930**	**1,443,504**

54 Generally, carbon pools vulnerable to anthropogenic changes are above-ground biomass and below-ground soil carbon between 30 cm and 1m (Murray et al., 2010).

55 The IPCC has established a tier system reflecting the degrees of certainty or accuracy of the carbon stock assessment. Tier 1 uses IPCC default values (i.e. biomass in different forest biomes, etc.) and simplified assumptions; it may have an error range of ± 50% for aboveground pools and ± 90% for the variable soil carbon pool. Tier 2 requires country-specific carbon data for key factors. Tier 3 requires highly specific inventory-type data on carbon stocks in different pools, and repeated measurements of key carbon stocks through time, which may also be supported by modelling.

56 For example, if 100 tonnes CO_2 is exposed to conversion and it is assumed to have a half-life of 5 years, 50 tonnes will remain at year five, 25 tonnes will remain at year ten, 12.5 tonnes will remain at year fifteen (and so on).

6.6.3.2 MARKET PRICE

Estimates of stocks of CO_2 equivalent in soil and biomass for the whole of Vanuatu ranged from 0.7 to 1.6 million tonnes (detail in Table 25).

Using a carbon price estimate of US$ 4.90/tCO_2eq (Forest Trends Ecosystem Marketplace and Bloomberg New Energy Finance 2014) Vanuatu could receive between US$ 8,000 and US$ 26,000 per year if carbon credits were sold in markets (based on a maximum 0.2% annual rate of habitat degradation), on the understanding that the market will pay only for avoided loss (Table 26).

TABLE 25 • Details of the carbon sequestration service in Vanuatu

Habitat	Habitat area (ha)	Annual rate of deforestation (% of total area/year)	Volume of carbon sequestered per hectare (tCO_2eq/yr/ha)		Soil and biomass stock (tCO_2eq/ha)	
			Min	Max	Min	Max
Mangroves	2,700	0.2%	0.12	23.98	900	1,900
Seagrass	1,500	0.2%	-9.4	50.22	300	500
Total			**-9.28**	**74.2**	**1,200**	**2,400**

TABLE 26 • Market price of carbon sequestration service in Vanuatu

Habitat	Annual volume of CO_2-eq not released (tCO_2eq/yr)		Value of carbon credit (US$/yr)	
	Minimum	Maximum	Minimum	Maximum
Mangroves	1,312	2,770	7,000	22,000
Seagrass	243	405	1,000	4,000
Total	1,555	3,175	8,000	26,000

6.6.4 UNCERTAINTY

The main sources of uncertainty are estimates of habitat areas, carbon sequestration rates, annual rates of deforestation and prices in the voluntary market for carbon credits. These four sources of uncertainty are important and difficult to reduce. The Department of Forestry in Vanuatu is assessing mangrove and seagrass habitat areas more precisely for Vanuatu.

6.6.5 SUSTAINABILITY

This ecosystem service is not extractive or damaging to marine ecosystems. However, destruction and degradation of mangrove and seagrass habitats from other uses and impacts is growing.

6.6.6 DISTRIBUTION

This ecosystem service produces benefits for the world community through reduced impacts of climate change and ocean acidification. The Vanuatu government could theoretically benefit from additional income to the public budget from selling carbon credits on the international market.

6.7 RESEARCH, EDUCATION AND MANAGEMENT

6.7.1 IDENTIFY

Marine and coastal ecosystems attract official development aid projects aimed at sustainable use and conservation as well as scientific researchers from around the world. They offer also education opportunities to students of all ages.

The surplus value of marine and coastal ecosystems as it pertains to biodiversity management and education in Vanuatu is the value of grants, scholarships and aid coming from overseas. In this valuation, with the help of the Ministry of Finance, we chronicled the aid and grant flows to Vanuatu in 2013.

6.7.2 QUANTIFY

The main transactions for international projects related to marine ecosystems under the Departments of Environment, Fisheries, and Meteorology are listed in Table 27.

TABLE 27 • List of research and conservation projects linked to marine ecosystems in Vanuatu, 2013

PROJECT
Green snail resource enhancement and management
Aquarium trade management plan—stage 1
Tafea rural fish market outlet
Compliance division computer
Enhancing coastal and marine ecosystem resilience to climate change impact
Vanuatu fisheries observer and port sampling program
Vanuatu cadet tuna fisheries observer upgrade course
Sea cucumber stock assessment
Sustainable management of marine resources
Vessel Monitoring System (VMS) assistance
Renovation of fisheries compliance division office
Tuna fisheries observer training program
Vanuatu climate change adaptation (VCCAP)
Vanuatu meteorological archive
Second national communications
HF radio for Torres group
Forecasting section technology upgrade
Pacific adaptation to climate change
Seismic and volcano activity in Vanuatu—towards an integrated network response
Agro-met workshop and digitisation program
Vanuatu REDD4 project
EC ACP (European Commission Africa, Caribbean and Pacific) Community Disaster Management capacity-building project
Mainstreaming disaster risk reduction in Vanuatu

PROJECT
Regional seismic travel/time and Non-Communicable Diseases capacity workshop
Increasing resilience to climate change and natural hazards
Increasing resilience to climate change and natural hazards – meteorological component
Reaching the last mile through integration of local climate and weather indicators
Pacific climate animation project
Oceania regional seismic network (ORSNET)
Facilitating communities and landholder initiated conservation activities
Development of the national biosafety framework of Vanuatu
Vanuatu strategic action programme for international waters project
Vatthe Ca sustainable community fishing project
Sarakata hydro dam allocation of funds
Development of HCFC phase-out management plan for Vanuatu
Institutional strengthening for Vanuatu—phase II (2nd year)
Support to get eligible CBD parties for carrying out 2010 biodiversity targets national assessments
Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) Vanuatu
Grassroots project funding for Clean Port Vila 2012
Prevention, control and management of invasive alien species in the Pacific Islands (Vanuatu)
National Biodiversity Strategy and Action Plan
National Biodiversity Strategy and Action Plan Review

Source: Ministry of Finance

6.7.3 VALUE

In 2013, preliminary figures indicate the value of research, education and management was Vt 434,000,000 (US$ 4,900,000). Without the presence of marine ecosystems these financial flows would not have been present in Vanuatu. Therefore, they represent a benefit for the Vanuatu economy. We also assume that most of these funds were spent in the nation in form of studies (consultancies), staff and assets.

6.7.4 UNCERTAINTY

The level of uncertainty in aid and grant flows received by the Government of Vanuatu in 2013 is relatively low as a high level of transparency is applied to all international projects in Vanuatu. The derived values may not include projects managed by the Vanuatu Kultural Senta, as they use different categories from nature conservation and resource management.

6.7.5 SUSTAINABILITY

This ecosystem service is not extractive or damaging to marine ecosystems, and in fact largely represents investments in better environmental management. As such it is considered to be sustainable.

6.7.6 DISTRIBUTION

The main beneficiaries of international aid and grant are local institutions, local communities and the private sector (experts and implementing agencies). However, a persistent criticism of international aid is that a large proportion of the benefits return to citizens of the donor countries or other wealthy countries in the form of salaries paid to international consultants and project managers.

6.8 OTHER VALUES

Other ecosystem services are also important in Vanuatu, even if they cannot be quantified or valued in monetary terms.

6.8.1 CULTURAL AND LIFESTYLE VALUES

All of Vanuatu's people treasure their ocean (T. Tevi, pers. comm.). There is a long tradition of connection with the sea as evidenced from the historical use of shells as money by the people of Vanuatu. Shells could be used in part or whole and woven into different shapes. The ni-Vanuatu also used shells, urchin arms and turtle shell for body ornamentation, conch shells to call people together, augur shells (Terebridae) as spearheads, the hard, sharp edges of the turtle limpet as a tool in cooking, coral rock to pound kava, and people travelled regularly between islands in canoes. These voyages were a traditional part of life and allowed for inter-island trading for both socioeconomic and ritual purposes.

Today fish and shellfish remain important sources of food for the ni-Vanuatu as both nourishment and in cultural ceremonies. Shellfish and other invertebrates are more traditionally gathered by the women. Giant clams, once the flesh is eaten, can serve as basins or can be carved into axes. Some local languages have the same word for giant clam and for axe. Palolo worms are still seen as a delicacy and can only be caught at specific times of the year.

Even the sand on the beach, literally, has stories to tell. In 2003, UNESCO proclaimed Vanuatu *sandroing* (sand drawing) to be a "masterpiece of the oral and intangible heritage of mankind". Vanuatu *sandroing* was also recognised as being of outstanding cultural value; it is used to leave messages, explain concepts and teach children. It is often accompanied by stories or song and is especially important in the northern islands of Vanuatu.

Customary stories are known and still told about the animals of the sea. The stories differ from island to island and even village to village, and include stories about turtles, the reef heron, the *nakato* (hermit crab), the black and white seasnake (*natopu*), an octopus, the swamp hen or the barracuda (Livingstone 2014a, 2014b, 2014c; Regenvanu 2014).

Marine resources were, and continue to be, subject to traditional marine resource management systems and about 113 local languages contain traditional environmental (including marine) knowledge (Hickey 2008). Some of the traditional marine resource management tools used in Vanuatu include resource ownership, seasonal controls, gear restriction, size limits, restrictions on access and tabu areas (temporary or permanent no-take areas) (Hickey 2006). These controls may be due to totemic affiliations, observations about the stock status, village hierarchy or roles, traditional calendars or customary celebrations, ceremonies and rules (Hickey 2006). The community polices itself and enforces compliance with the traditional management system (F. Hickey, pers. comm.). In addition to resource management, the exchange and sharing of resources, including marine resources, are common and form part of the customary suite of obligations that ties kin (Hickey 2008; Johannes and Hickey 2004). Although faltering in places, the traditional culture, language, knowledge and resource management surrounding marine resources in Vanuatu remain an important part of life today and are an integral part of the definition of society and communities throughout the country (F. Hickey, pers. comm.).

These examples of cultural heritage and values, and the language used to convey them, are threatened when the marine resources on which they depend decline (e.g. reduced populations of giant clam shells, some reef fish populations, turtles). Even sand mining and hardening of shorelines can impact on beaches and, then, that “masterpiece of intangible heritage to mankind” *sandroing*.

In Vanuatu, the cash economy is still under-developed. Therefore, the value that local communities attribute to money, and its function in life, differs widely from common economic assumptions. Island societies assign value to things that lack exchange equivalents, or relative prices, and which therefore are difficult to include in a *total economic value*. Three categories of cultural values of marine resources can be described (adapted from Laurans et al. 2013):

- the degree of familiarity of islanders with the reef, which can be measured by the density of place names per square kilometre and the number of fishes named locally. These two metrics are a proxy for both the *non-use value* of the reef and its *use value* (Pacific Islanders name only what they use).
- the role of the reef in the identity of the village community. The highest value is attached to the place where the canoe of the founding ancestor of the island population first landed.
- the role of the reef in the social and political positioning of the community towards other island communities. The highest values are found among reef fishing clans (as in New Caledonia (Leblic 1999)) and among communities where the alliance relationships are built on sharing of fishery products, including turtles, as in Tanna Island (Bonnemaison 1986).

6.8.2 OTHER VALUES

In Vanuatu, there are also other values ascribed to marine ecosystems that are not further analysed in this report. For example, people may also value the option to use marine resources in the future, or enjoy knowing that others are using the resources. In the future, marine bioprospecting may also bring benefits to Vanuatu. *Ecosystem functions* that support the ecosystem services analysed in this report are fundamental to the ability of marine environments to provide benefits to people. These functions are described in more detail in Appendix III and have inherent value as well. These values have not been considered in this report. Therefore, the value ascribed in this report to the marine and coastal ecosystems of Vanuatu should be considered a minimum value.

6.9 SUMMARY OF RESULTS

Some of these ecosystem services can conflict with each other (e.g. minerals and aggregate mining and marine tourism) but the valuations conducted here have inherently addressed this conflict. For example, if mining has reduced the value of marine tourism, the lower value for tourism is the one reflected in this analysis. Any unsustainable use of ecosystem services (e.g. overfishing) may also lead to a lower value of these services in the future.

The sum of all the ecosystem service values provided in this report (Table 1, Table 2, pages 1–2) represents a minimum value of Vanuatu's marine resources because not all the ecosystem services were able to be valued.

7. RECOMMENDATIONS AND SUGGESTIONS

To maximise impact on policy-making we recommend communication of the results of this study to the following stakeholders using tailor-made communication products (adapted from Laurans et al. (2013)):

- Government planners. We recommend incorporating green *welfare* accounting in government monitoring and planning activities (TEEB 2010), for example by using the Inclusive Wealth Index[57] launched at Rio +20 (UNU-IHDP and UNEP 2012). An example of this application is the use of the World Bank natural capital accounting approach in New Caledonia (Brelaud et al. 2009).
- National and departmental planners building national development strategies and plans whether for the nation as a whole or for particular sectors (e.g. tourism).
- Government environmental agencies that intend to assess and communicate the ecosystem services that their actions protect or improve sustainable use of marine and coastal resources. For instance, the results of the *cost-benefit analysis* of a marine protected area in North Efate were used by the local environmental department to influence budget allocation.
- Other environmental agencies and conservation NGOs that need to justify projects when arguments regarding the generic value of nature and uniqueness of ecosystems are considered insufficient. For example, the valuation of mangroves was used to raise awareness of the role of these ecosystems in human wellbeing by the IUCN MESCAL project in Vanuatu (Pascal 2014); or valuation of the costs of wild versus cultured live corals to inform public policy (Lal and Kinch 2005).

Development banks, for which valuations highlight how conservation has helped the local or regional economy and the people who depend on the managed ecosystems (e.g. *cost-benefit analysis* of community-based marine managed areas in Vanuatu; Pascal 2010)

- Local stakeholders such as customary chiefs, resource users and marine protected area managers who could use the results to highlight benefits for local users and members of the community. For example, the community-based marine managed area valuation (Pascal 2010) helped put forward benefits and equity distribution that, perhaps, were not perceived by the inhabitants. They were used also as a tool in the community for making trade-offs between the short and medium term.

57 The Inclusive Wealth, which looks beyond the traditional economic and development yardsticks of Gross Domestic Product and the Human Development Index to include a full range of assets such as manufactured, human and natural capital, shows governments the true state of their nation's wealth and the sustainability of its growth.

8. CAVEATS AND CONSIDERATIONS

One of the main challenges in valuing marine and coastal ecosystem services in Vanuatu is the customary community context that renders inapplicable the standard economic assumption of individual maximisation of *welfare*. Many natural resources in the Pacific Island territories are communally owned (without formally defined or recorded boundaries), which affects how those resources are used and managed. Community life implies the existence of many links among people and a constant inter-connection with the other households. Many services and goods are given without direct and rapid compensation among families or the community. For example, it is usual that a day of the week is dedicated to some work decided by the village council that will benefit the community or a family without any kind of remuneration (except from receiving the same kind of assistance from the community in the future or from using community goods). Un-remunerated help and exchange of services are very common (Johannes and Hickey 2004). Another feature of the Vanuatu context is customary obligations to kin and reciprocity of exchange in material possessions or cash, whereby the measure of a person is not by how much they own, but by how much they give (Bensa and Freyss 1994).

In that sense, the cash economy in Vanuatu is still under-developed. Therefore, the value that local communities attribute to money, and its function in life, differs widely from common economic assumptions. Island societies assign value to things that lack exchange equivalents, or relative prices, and which therefore cannot be included in a total economic valuation.

Methodological and data caveats are discussed in detail in Salcone et al. (2015).

9. FUTURE DIRECTIONS

Ecosystem services are increasingly becoming central in general discussions on marine and coastal management. From a conservation point of view, this is positive, in that it will help advocate better management of coral reef ecosystems. Significant progress has been made in economic valuation over the last 20 years, and the economic invisibility of ecosystems and biodiversity has no doubt been reduced over these years, although a lot more needs to be done (TEEB 2010).

Valuations of ecosystem services can play a role in designing policy instruments such as payment for ecosystem services with equitably identified beneficiaries, and can inform public and investment decisions, legal proceedings, negotiations, budgetary decisions, resource management and use choices in local and national development planning. Our experience suggests that ecosystem valuation studies are not yet fully used to play such roles. A balance between research effort for knowledge and science for policy is needed to build the credibility of the *ecosystem service approach*.

Using information on ecosystem services as performance measures for government, multilateral agencies and private investments will result in improved project prioritisation and increased attractiveness of investments in sustainable use of marine and coastal resources. This has the opportunity to expand the funding base away from purely 'conservation' investments. The ecosystem services approach can bring concrete information about potential returns for private sources of financing for conservation (Parker et al. 2012).

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12. 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.

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.

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

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.

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.

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.

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.

Profit: The difference between the revenue received by a firm and the costs incurred in the production of goods and services (see also producer surplus).

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).

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.

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, service, or avoid a change in condition.

13. APPENDIX II RECORD OF MEETINGS AND WORKSHOP PARTICIPANTS

7–8 OCTOBER 2013

Dr Sangeeta Mangubhai, MACBIO Senior Project Officer (to April 2014), conducted meetings with the following individuals, introduced the project and the three main components of MACBIO including ecosystem service valuation.

Mr Albert Williams	Director, Department of Environmental Protection and Conservation
Ms Donna Kalfatak	Department of Environmental Protection and Conservation
Ms Touasi Tiwok	Department of Environmental Protection and Conservation
Mr Trinison Tari	Department of Environmental Protection and Conservation
Mr Sompet Gereva	Department of Fisheries
Mr Lency Dick	Department of Fisheries
Dr Andrina Thomas	Live and Learn Vanuatu
Ms Anjali Nelson	Live and Learn Vanuatu
Mr Wan Smol Bag	GIZ Vanuatu
Mr Bernard O'Callaghan	Consultants, GEF/UNDP project
Ms Virginia Smith	Consultants, GEF/UNDP project

20–24 MAY 2014

Dr Leanne Fernandes, MACBIO Senior Project Advisor (from April 2014) held meetings with:

Ms Donna Kalfatak	Department of Environmental Protection and Conservation
Mr Albert Williams	Acting Senior Biodiversity Officer, Department of Climate Change
Mr Trinison Tari	Senior Education and Information Officer, Department of Environmental Protection and Conservation
Mr Sompet Gereva	Department of Fisheries
Mr David Talo	Dissemination Officer, Department of National Statistics
Mr Toney Tevi	National Coordinator, Maritime Boundary Delimitation Project, Ministry of Foreign Affairs
Mr Paul Gambetta	Lands Department
Mr Brian Phillips	Manager, Climate Change and Disaster Risk Reduction Project Management Unit, Office of Climate Change
Dr Andrina Thomas	Live and Learn Vanuatu
Ms Rolenas Bareleo	Secretariat of the Pacific Community
Mr Stanely Wapot	Melanesian Spearhead Group Secretariat

22–25 JULY 2014

Dr Leanne Fernandes, Senior Project Advisor, MACBIO held meetings with:

Mr Jotham Napat	Vanuatu Meteorology and Geo-hazards Department
Mr Shadreck Wilegtabit	National Disaster Management Office
Mr Sompert Rena	Department of Fisheries
The Hon. Michel Kalworai	Secretary-General Shefa Provincial Government Council
Mr Brian Phillips	Program Management Unit, Department of Climate Change and Disaster Risk Management

Ms Touasi Tiwok	Department of Environment
Mr David Lees	Department of Public Works
Dr Christopher Bartlett	Deutsche Gesellschaft für Internationale Zusammenarbeit
Dr Andrina Thomas	Live and Learn Vanuatu
Mr Albert Williams	Acting Deputy-General Department of Environment
Mr Paul Gambetta	Department of Lands
Mr Naelo Tosso	Department of Lands

4 SEPTEMBER 2014

A workshop on economic valuation of marine and coastal ecosystem services was held in Port Villa, Vanuatu. Attendees were:

Mr Yuette Tari	Coastal Community Adaptation Project
Ms Melinda Lessa	Secretariat of the Pacific Community /Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Federal Enterprise for International Cooperation)
Mr Bani Arudovo	University of the South Pacific/European Union Association of Certified Chartered Accountants
Mr Josain Vivaliliu	Live and Learn Vanuatu
Ms Glarinda Andre	Live and Learn Vanuatu
Ms Anjali Nelson	Live and Learn Vanuatu
Mr Touasi Tiwok	Department of Environmental Protection and Conservation
Ms Sarah Graham	Shefa Tourism
Ms Dianne Hambrook	Shefa Tourism
Ms Janet Jack	United Nations Development Programme
Mr Jake A. Tambeanu	Department of Tourism
Mr Malcom Dalesa	Project Management Unit, Vanuatu Meteorological and Geo-Hazards Department
Mr Jerry Spooner	Department of Tourism
Mr Epharam Kalsakau	Vanuatu Council of Trade Union
Mr Matthew Hardwick	United Nation Development Programme
Ms Kathy Stephens	Shefa Tourism
Mr Rolenas T. Bareleo	Secretariat of the Pacific Community
Mr Erie Sami	Department of Geology, Mines and Water Resources
Ms Lilly Fatdol	Department of Environmental Protection and Conservation
Ms Dorallyne Solomon	Department of Strategic Policy, Planning and Aid Coordination
Mr Ian Lercet	Public Works Department
Mr Uravo Natulei	Public Works Department
Mr Amos Ralo	Save the Children
Mr George Borugu	Department of Tourism
Mr Job Dalesa	Presbyterian Church in Vanuatu
Ms Nileita Sober	Secretariat of the Pacific Community/Deutsche Gesellschaft für Internationale Zusammenarbeit
Mr Phillip Mero	National Disaster Management Office
Mr Tony Kaltony	Department of Finance

1–5 SEPTEMBER 2014

Dr Leanne Fernandes and Mr Jacob Salcone had one-on-one meetings with:

Mr Jochum Napat	Office of Disaster Risk Reduction, Department of Meteorology and Geo-Hazards
Mr Richard Balkonan	Ministry of Foreign Affairs
Mr Martin Sokoman	Department of Lands, Surveyor-General of Vanuatu
Mr Bethwell Solomon	Prime Minister's Department of Strategic Policy, Planning and Aid Coordination, Agriculture, Land, and Marine Sector Analyst
Mr Jason Rowpani	Department of Fisheries
Mr Alan Nafuki	Presbyterian Church Elder and ex-Government Minister

2–6 FEBRUARY 2015

Dr Leanne Fernandes and Mr Jacob Salcone had one-on-one meetings with:

Ms Donna Kalfatak	Department of Environment Protection and Conservation
Mr Ben Titus	Department of Geology, Mines and Water Resources
Mr Kalo Pakua	Director of Fisheries
Mr Toney Tevi	Ministry of Foreign Affairs
Ms Touasi Tiwok	Conservation Officer, Department of Environment Protection and Conservation

Dr Leanne Fernandes and Mr Jacob Salcone gave a presentation on the project to:

Ms Lilly Fatdol	Department of Environment Protection and Conservation, GEF Pacific Alliance for Sustainability
Ms Naomay Tor	Department of Environment Protection and Conservation
Mr Charlington Leo	Vanuatu National Statistics Office
Mr Bani Arudovo	University of the South Pacific, Climate Change
Ms Rosine Lawac	Department of Geology, Mines and Water Resources
Mr Malcolm Dalesa	Project Management Unit, Vanuatu Meteorological and Geo-Hazards Department
Ms Janet Tambeana	Department of Tourism
Mr Stanley Wapot	Melanesian Spearhead Group Secretariat
Ms Touasi Tiwok	Department of Environment Protection and Conservation
Ms Anu Simnovec	Live and Learn
Ms Anjali Nelson	Live and Learn
Ms Glarinda Andre	Live and Learn
Dr Christopher Bartlett	Deutsche Gesellschaft für Internationale Zusammenarbeit
Mr Graham Waka	Public Works Department
Mr Jim Muldoon	MACBIO
Mr Pita Neihapi	SPC-Fisheries
Mr Rolenas Bareleo	SPC- Fisheries

Further helpful discussions were held with Ms Adela Issachar and Mr Graham Nimoho on 26 April and 2 May 2015 regarding preliminary results by Dr Leanne Fernandes and Mr Vatu Molisa.

14. APPENDIX III ECOLOGICAL FUNCTIONS SUPPORTING MARINE ECOSYSTEM SERVISCES

Ecosystem functions underpin all the ecosystem services described in this report. For this reason, here we describe some of the processes and environmental attributes that are essential for viable ecosystem functioning.

14.1 BIOMASS PRODUCTION

The description of this process is based on the work of Done et al. (1996) and Pollnac (2007). Coral reef and healthy mangrove ecosystems are diverse communities of marine organisms in a highly productive marine environment which is also low in nutrients. Productivity refers here to the large volume of carbon fixation that occurs in these ecosystems.

Productivity measurements have shown that coral reefs and mangroves are among the most productive of all marine ecosystems (Table 28; Done et al. 1996; Barnaud and Fustec 2007).

TABLE 28 • Primary production of ecosystems

Ecosystem	Average primary production (g dry matter/m²/yr)
Coral reefs	2500
Tropical forests	2200
Mangroves	2000
Estuaries	1500
Template forests (coniferous)	1300
Agroecosystems	650
Upwelling zones	500
Continental platform	360
Lakes and rivers	250
Open ocean	125

Source: Barnaud and Fustec (2007)

Moreover, this productivity is obtained in spite of the relative absence of dissolved nutrients (N and P) in the surrounding oligotrophic waters. For reefs, the secret to this success is recycling of nitrogen via the symbiosis between algae and coral polyps. The algal symbionts function as nitrogen fixers in nutrient-poor environments, somewhat like legumes in agricultural ecosystems. Algae and phytoplankton also ensure the transformation of nutrients in marine environments into biomass available for other plant and animal species (Harborne et al. 2006). Algae and phytoplankton are autotrophs, since they produce organic matter from inorganic substances (water, CO_2,minerals), in the environment. Mangroves produce a large amount of organic material due to their structure. This production is the basis of a complex food web in tropical coastal environments. Therefore, mangroves ecosystems support abundant marine life and often serve as spawning or nursery grounds. They also provide organic carbon to coral reefs. If the nutrient recycling chain is interrupted by the removal of mangroves, coral reefs would be deprived of this important element (Ruitenbeek 1994).

14.2 HABITAT COMPLEXITY

The relationship between coral reefs, mangroves and fish stocks has attracted much attention in recent years (Worm et al. 2006; Mumby and Steneck 2008). Two meta-analyses concluded that half or more of herbivorous reef fish species (including commercial species in the families Scaridae and Acanthuridae) decrease significantly in abundance after a bleaching event (Wilson et al. 2006; Mumby and Steneck 2008). This impact on the abundance and diversity of fish and invertebrates is partly explained by their dependence on habitats provided by coral reefs or mangroves for settlement or larval feeding (Wilson et al. 2006). Some studies have shown that over 60% of the fish disappear within three years following a reduction of more than 10% live coral cover (Jones et al. 2004).

Loss of habitat complexity may increase the effectiveness of predators and thus influence the density of small fish (Hixon and Beets 1993). It also influences the diversity of invertebrate species (Idjadi and Edmunds 2006). Even the recruitment of fish that do not depend on live coral cover declined in degraded areas.

Many fish species move between reef, mangroves and the lagoon. Indeed almost half move between these ecosystems at different life stages (Mumby and Steneck 2008). For mangroves, aerial roots support the fauna and flora of the tropical coasts: algae, sponges, molluscs (including oysters). The fish take shelter among the roots, in the calm, nutrient rich waters. It is not uncommon to find schools of small, pelagic fishes that attract predators. Juvenile fish migrate from mangroves to nearby reefs as they grow (Harborne et al. 2006).

14.3 NURSERY HABITATS

Nursery habitats are areas which provide critical living space for eggs, larvae, juveniles and sub-adults of many coastal and pelagic marine species. They provide food, shelter, space and pathways to adult habitats for species. Nursery areas include estuaries, shallow banks, mangroves, coastal forests and wetlands, seagrass beds, coral and rock reefs, seamounts, and even static portions of some parts of oceans (such as the Sargasso Sea).

A nursery habitat is valuable to a species only insofar as it is accessible. Eggs, larvae, and young organisms rely partly on currents to reach nursery areas. Current flows facilitate dispersal to and from the nursery site while at the same time, boundary currents allow for larval retention. Human interference with current flows can impact on dispersal patterns. Once larvae are settled, they need to be able to stay and grow — thus nurseries are relatively static areas that are able to retain larvae and young animals until they grow large enough to leave the site on their own. Fish, sea turtles, marine mammals and invertebrates that have grown in nursery areas must be able to successfully access adult habitats (or other nursery habitats for other, non-adult life stages), from these sites (Tewfik and Bene 2003).

Nursery sites provide food through nutrient loading and prey availability. A nursery habitat increases the survival of young organisms if sufficient food is available. For primary consumers, this food takes the form of plant life: phytoplankton, algae and macroalgae. For carnivorous and omnivorous species, nursery habitat must supply prey. Mangroves, estuaries and seagrass beds are notable for their productivity. Nutrients arrive from elsewhere via rivers, run-off, currents and upwelling. Nursery habitats that are also able to produce food on site retain many nutrients through efficient recycling. The wide availability of nutrients in turn fosters blooms of copepods and other prey species.

Nursery habitats are often physically complex places with much spatial heterogeneity. They provide hiding places as refuges from predators. Survivorship is significantly higher in areas with reduced predation than in the open ocean. Some nurseries simply provide a habitat that predators do not generally use (e.g. areas with shallow, calm waters or low salinity).

Nurseries also provide the space needed for maintaining optimal densities of individuals. Most marine organisms are highly fecund, producing an abundance of juveniles to offset the natural mortality caused by predation, including human fishing pressure. Vast numbers of eggs and juveniles from many different species find their way to nursery areas, and once there they need space to grow. Thus, the most valuable nursery areas are those that provide all the functions above with sufficient space to support large numbers of growing organisms.

In this way, marine nurseries provide refuge and food to a wide array of species, and in so doing, contribute important ecosystem services.

14.4 CONNECTIVITY

In the marine environment, all habitats are ultimately connected by water (Figure 10). Currents and mobile organisms themselves provide the links between habitats such as coral reefs, nursery areas, and places where organisms move to feed or breed.

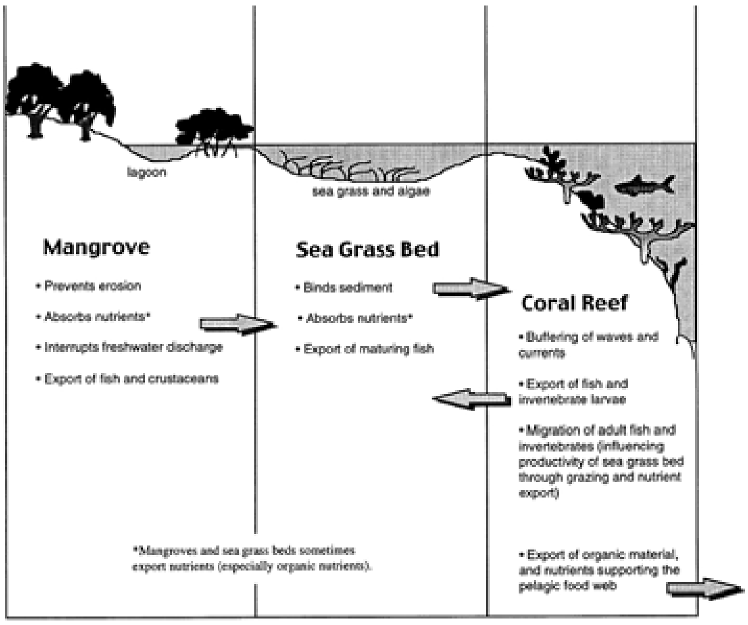

FIGURE 10 • Interactions in the tropical seascape, showing the connections between mangroves, seagrass beds and coral reefs. Source: Moberg and Folke (1999)

Connectivity between habitats for fisheries is estimated through a production function in terms of the changes in *consumer* and *producer surpluses* from the marketed catch (François et al. 2012). The standard approach adopted in coastal habitat–fishery models is to allow specific areas to serve as a proxy for the productivity contribution of the nursery and habitat function. It is necessary to model how changes in the stock or biological population due to habitat changes may affect the future flow of benefits.

For this study, we assumed that all reef-, seagrass- and mangrove-associated species caught in coastal fisheries have benefited to some degree from at least one aspect of coastal and marine ecosystem processes (e.g. habitat complexity or nursery habitats).

15. APPENDIX IV CLEAN DEVELOPMENT MECHANISM AND THE CARBON PRICE

This appendix explains the origin of the carbon prices used in Section 6.6.3.

In order to include an estimate of the price of carbon valid for the economic valuation approach, it is necessary to be clear about how to generate such price and in which market it will be traded.

The Clean Development Mechanism (CDM) is a mechanism of the Kyoto Protocol. It allows governments and companies in industrialised countries to engage in emission reduction projects in developing countries to earn Certified Emission Reductions (CER), so they can meet emission targets set in the Protocol. Each certificate equivalent to 1 tonne CO_2eq can be traded and sold in international financial markets. CERs are obtained by driving projects to mitigate greenhouse gases through actions promoting clean energy or reducing consumption (brown credit), afforestation and reforestation (green credits).

The CDM is one of the most successful mechanisms of the Protocol, as it has been selected as the model of certificate designed by the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC gave rise to the global carbon market, which currently constitutes one of the most important mechanisms and incentives to mitigate emissions of greenhouse gases, as it is the primary tool for protocol countries to meet agreed targets for reducing emissions (Nellemann et al. 2009).

Currently there are two types of carbon markets: compliance markets and voluntary markets. Compliance markets are used by companies and governments that are obliged by law not to exceed a quota of emissions of greenhouse gases. Carbon credits are traded in the market to enable parties to meet their emission reduction obligations. This market is used as the basis of our price valuation.

Voluntary carbon markets may be used by any country, institution or company wishing to produce or purchase carbon emissions for different reasons (e.g. reputation, certifications). They receive credits called Verified Emission Reductions (VER)[58] or Verified Carbon Standard (VCS)[59].

Although credits from initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) are the best suited to the characteristics of mangrove ecosystems, they are still not included in the regulated market as CER (Gordon et al. 2011). Because compliance standards do not yet account for REDD+ related offsets, mangrove and seagrass carbon finance through verified emissions reductions must come through the voluntary market. Although major voluntary offset creditors such as the VCS and Climate Action Reserve have yet to approve any blue carbon projects, future projects could occur on the basis of current REDD standards.

Additionally, the most recent version of the VCS Agriculture, Forestry and Other Land Use requirements include peatland rewetting and conservation (Gordon et al. 2011). Coastal lands with peat soils could be eligible for voluntary credits through these peatland requirements. Moreover, VCS is in the process of approving wetland mitigation standards that will likely include coastal habitats.

The future of coastal habitat protection through the voluntary carbon market rests on two factors: (1) the extent to which REDD projects in voluntary markets can incorporate blue carbon, and (2) the development of blue carbon standards in the voluntary market. According to the REDD+ methodology in the VCS, project areas may include forested wetlands (including mangroves) as long as these wetlands contain no peat, which is dealt with separately by VCS (Gordon et al. 2011).

58 The most popular type of carbon credit used to offset emissions around the world voluntarily is a VER, a Verified or Voluntary Emission Reduction unit and there are many different types. Before projects deliver credits used for compliance purposes such as CERs they can produce VERs. These credits can be verified to a number of specific standards, including the Gold Standard. Not all projects go on to register within the CDM, often due to the size of the project and the inhibitive costs associated with compliance registration, so their choice of one or more of these voluntary standards is made based on its overall viability and compatibility to them.

59 VCS credits or Voluntary Carbon Units (VCU) must be *real*; the abatement must have occurred; they must be additional by going beyond business-as-usual activities, measurable, permanent, not temporarily displace emissions; and the abatement must be independently verified and unique so it cannot be used more than once to offset emissions. The VCS is the most widely known and chosen standards in the voluntary market due to its Kyoto compatibility as well as its ability to accommodate a wide range of project types and methodologies. (www.carbonplanet.com)

In this study prices observed from compliance markets are used as a proxy for blue carbon credits from mangroves and seagrasses.

The voluntary market is the only option for existing payments for REDD-related carbon credits. In 2010, the voluntary market purchased approximately 131.2 million tCO_2e (Gordon et al. 2011). Of this amount, 30.1 million tCO_2e stemmed from forest carbon projects with a *market value* of US$ 178 million. REDD credits supplied between 17.8 and 19.5 million tCO_2e to the voluntary market (Gordon et al. 2011). The average price for a REDD credit in 2010 was US$ 5/tCO_2e; the average forest credit price was US$ 5.5, and the average voluntary credit price was US$ 6.9. The price range of all voluntary credits (including forest credits) remains extremely high. Prices in the voluntary market range from US$ 0.01 to US$ 136.3/tCO_2e. Forest carbon credits in the voluntary market have a smaller range, with a maximum price of approximately US$ 34/tCO_2e. The majority of voluntary credits as a percentage of the total market came from the VCS. VCS prices average US$ 4/tCO_2e. Latin America provided almost all (89%) of the REDD voluntary credits (Murray et al. 2010).

However, demand for REDD carbon credits is difficult to predict and remains subject to pending regulations (post-2012 UNFCCC protocol and California's Global Warming Solutions Act (AB32)). Estimates of future demand for blue carbon credits are highly speculative (Murray et al. 2010; Point Carbon 2010; Gordon et al. 2011). The comparative analysis of CER should provide useful insights (Sifleet et al. 2011).

The price at which CERs are traded is generated in the financial market; it is characterised by volatility in prices and depends on agents' expectations, the success of projects and the global economic situation, among other features (Figure 11). The cost for biomass carbon credits dropped from US$ 12 to US$ 10 between 2009 and 2010. At the same time, agroforestry carbon credits doubled in value from US$ 5 in 2009 to US$ 10 in 2010. The most expensive carbon credits in 2010 (US$ 18.1) were those produced by offset projects in Oceania. In Europe, prices in 2010 were a little over US$ 11 per credit. In the same year, US-produced credits were transacted at the lowest value among regions, at US$ 4.9 per credit.

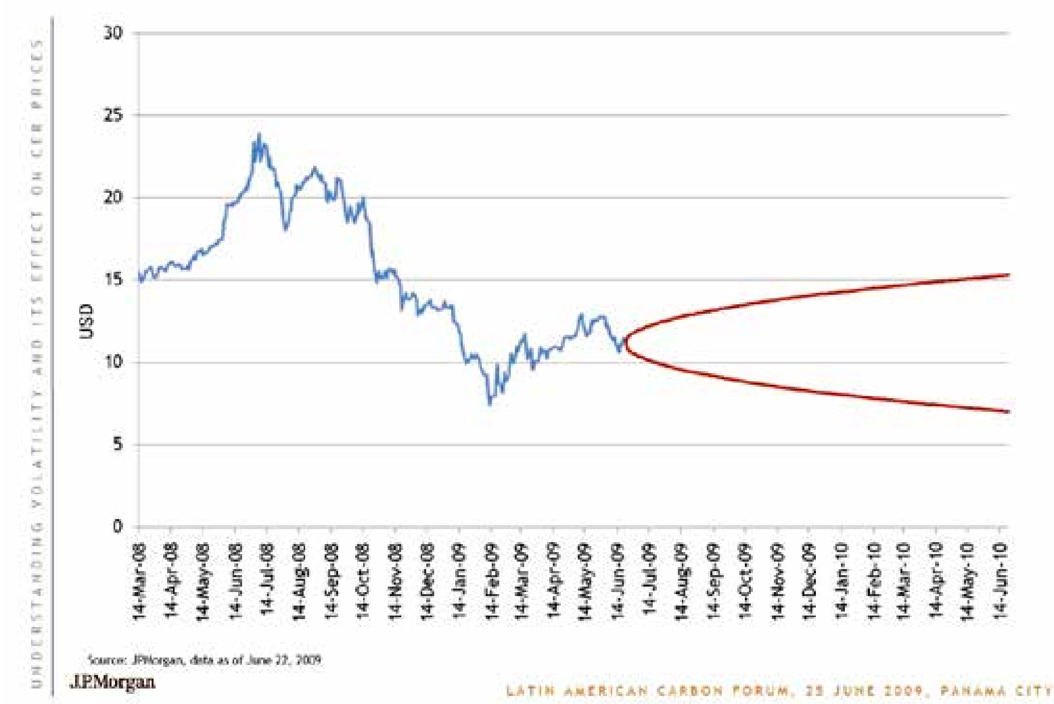

FIGURE 11 • Price simulations of CER. Source: JP Morgan 2009

The estimated price per unit of emission reduction is based on the analysis of historical transactions of EUA (European Union Allowances) on the European Climate Exchange (e.g. Figure 12). These transactions as EU-ETS (EU Emissions Trading System) or Kyoto-CER in 2010 represented more than 80% of transactions in global carbon markets (12 000 million tCO_2e since 2006).

An average price for the period of this study has been estimated based on the results of different surveys of CER and VCS (Point Carbon 2010; Gordon et al. 2011; Sifleet et al. 2011).

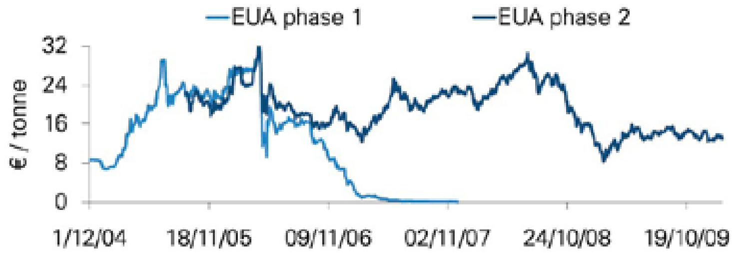

FIGURE 12 • Market prices EU-ETS, 2004–2009. Source: Point Carbon. Price at 30 December 2011: €6.70/t

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