# ECONOMIC VALUATION OF MARINE AND COASTAL ECOSYSTEM SERVICES IN THE PACIFIC

## GUIDANCE MANUAL

MACBIO

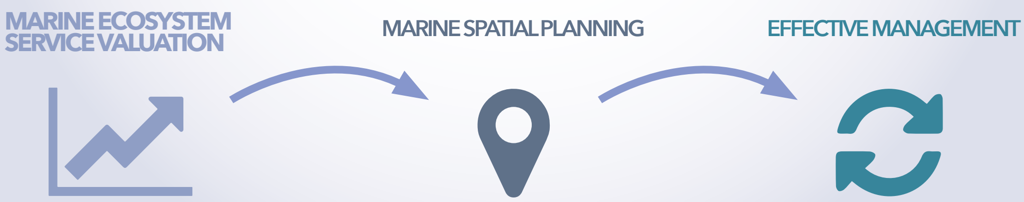
Marine and Coastal Biodiversity Management in Pacific Island Countries

# 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 national economic assessments of five Pacific island countries' 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**.




www.macbio-pacific.info

# ECONOMIC VALUATION OF MARINE AND COASTAL ECOSYSTEM SERVICES IN THE PACIFIC

# GUIDANCE MANUAL

Authors: Jacob Salcone, Luke Brander, Andrew Seidl

Editor: Leanne Fernandes

Citation: Salcone J, L Brander, A Seidl 2016 Guidance manual on economic valuation of marine and coastal ecosystem services in the Pacific. Report to the MACBIO Project (GIZ, IUCN, SPREP): Suva, Fiji.

2016

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

SPREP Secretariat of the Pacific Regional Environment Programme

IUCN

giz

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

This document has been produced with funds provided by the International Climate Initiative (IKI). BMUB supports this initiative on the basis of a decision adopted by the German Bundestag. The views expressed herein should not be taken, in any way, to reflect the official opinion of the Federal Government of Germany.



*Recommended citation: Salcone J, L Brander, A Seidl 2016 Guidance manual on economic valuation of marine and coastal ecosystem services in the Pacific. Report to the MACBIO Project (GIZ, IUCN, SPREP): Suva, Fiji. 48pp.*

.

MACBIO

Marine and Coastal Biodiversity Management
in Pacific Island Countries

# CONTENTS


1 Introduction 1
1.1 The purpose of this guidance manual 1
1.2 Who should use this guidance manual? 1
1.3 How to use this guidance manual 2

2 The case for economic valuation of ecosystem services 3
2.1 The case for economic valuation of ecosystem services 3
2.2 The TEEB approach 5

3 Concepts 7
3.1 Ecosystem services 7
3.2 Economic value 9
3.3 Total economic value 10
3.4 Exchange value and value-added 10

4 Economic valuation methods 11
4.1 Valuation methods 11
4.2 Other methodological issues 12

5 Guidance on valuation of marine and coastal ecosystem services 17
5.1 Fishing 17
5.2 Minerals and mining 21
5.3 Tourism and recreation 22
5.4 Coastal protection 25
5.5 Carbon sequestration 29
5.6 Research, education and management 34

6 Concluding remarks 35

7 Bibliography 37

ANNEX I: Other guidelines and manuals 39
APPENDIX I: Glossary 41

# ACKNOWLEDGEMENTS

The development of this manual has been initiated by the Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project, implemented jointly by the International Union for Conservation of Nature (IUCN), the Secretariat of the Pacific Regional Environment Programme (SPREP) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, German Agency for International Cooperation), and financed by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) under its International Climate Initiative. The authors would like to acknowledge the support and contribution of the following economists, ecologists, and government employees who supported or contributed to the development of this manual: Marco Arena, Ricardo Gonzales, Nicolas Pascal, Vina Ram-Bidesi, Iete Roautu, Paula Holland, Marita Manley and Anna Rios-Wilkes.

SPREP Secretariat of the Pacific Regional Environment Programme

IUCN

giz

On behalf of:
Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety
of the Federal Republic of Germany

# 1 INTRODUCTION

## 1.1 THE PURPOSE OF THIS GUIDANCE MANUAL

The purpose of this guidance manual is to show how the value of marine and coastal ecosystem services can be estimated and used to support decisions about the use and management of marine ecosystems in the Pacific. It is designed to help a broad audience of conservation managers, government officials, private sector managers, NGOs, and statisticians to understand and apply the available economic methods for valuing marine and coastal ecosystem services to inform the decisions that they make.

To this end, the manual provides:

1. A simple but technical introduction to the economic valuation methods that are applicable to marine and coastal ecosystem services;
2. An explanation of the limitations of each method and potential uncertainties; and
3. Examples of the use of each valuation method, with a focus on valuations of marine and coastal ecosystem services in the Pacific Island Countries and Territories (PICTs).

## 1.2 WHO SHOULD USE THIS GUIDANCE MANUAL?

The manual has been designed to help anyone in the Pacific involved in conducting economic assessments of marine and coastal ecosystem services to understand and apply the available set of valuation methods. Potential users include:

- **Middle-level conservation managers**. Economic valuation is potentially a useful source of information for demonstrating the benefits of conservation or for assessing alternative conservation measures.
- **Policy makers in sector ministries (e.g. environment, forestry, agriculture)**. Economic valuation may be used in policy appraisal, damage assessment, or designing incentive- and market-based mechanisms for ecosystem services (e.g. Biodiversity Finance Initiative, BIOFIN[1]).
- **The private sector.** Private enterprises are increasingly interested in understanding the value of ecosystem services (e.g. the Natural Capital Protocol[2]), either as inputs to production or as outputs (external costs and benefits) to society. Economic valuation is potentially useful as a source of information for full-cost accounting, triple bottom line analysis, and calculating environmental profit and loss.
- **Non-government Organisations and Civil Society**. Economic valuation can be used to communicate the importance of ecosystems and biodiversity to society. The use of economic language can be very effective in communicating this message to some stakeholders and decision makers.
- **Statisticians and accountants**. Several international initiatives are underway to incorporate ecosystem service values into national accounts and reporting systems (e.g. under the Convention on Biological Diversity Aichi Target 2; Wealth Accounting and Valuation of Ecosystem Services, WAVES[3]; System of Environmental Economic Accounts, SEEA[4]). Economic valuation provides a means to do this.

1 www.biodiversityfinance.net
2 http://naturalcapitalcoalition.org/protocol/
3 https://www.wavespartnership.org/
4 http://unstats.un.org/unsd/envaccounting/seea.asp

# **1.3** HOW TO USE THIS GUIDANCE MANUAL

To be able to use the manual, a basic understanding and experience of applied environmental economics is useful, but not required. The aim is to provide a practical handbook to guide economic valuation of marine and coastal ecosystem services.

This manual has been developed in the context of a project that aims to estimate the values of key marine and coastal ecosystem services in five island countries in the South Pacific.[5] It is therefore tailored to the level of technical expertise, resources and data availability in those countries. In particular, the valuation methods outlined in this manual make use of secondary data only. Valuation methods that require collection of primary data, for example through surveys, are not presented in this manual. Detailed information and guidance on the use of valuation methods that require collection of primary data can be found in the sources listed in Annex I.

The manual is organised into sections. Section 2 explains the role of information on the economic value of ecosystem services in decisions about the marine environment. It makes the case for economic valuation of ecosystem services and outlines the TEEB (The Economics of Ecosystems and Biodiversity) approach to ecosystem service assessment (TEEB, 2013). Section 3 provides an explanation of key concepts used in this manual, including ecosystem services and economic value. Section 4 outlines the full set of economic valuation methods, including revealed preferences of producers, revealed preferences of consumers, replacement and avoided costs, and stated preferences. Section 5 provides practical guidance on how to estimate economic values for a set of seven key marine and coastal ecosystem services, including worked examples.

5 The Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project is implemented jointly by the International Union for Conservation of Nature (IUCN) and the German Agency for International Cooperation (GIZ), and financed by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) under its International Climate Initiative. The five countries are Fiji, Solomon Islands, Kiribati, Vanuatu and Tonga.

# 2 THE CASE FOR ECONOMIC VALUATION OF ECOSYSTEM SERVICES

## 2.1 THE CASE FOR ECONOMIC VALUATION OF ECOSYSTEM SERVICES

Economic valuation is simply a means to describe how valuable the natural world is to us. Estimating an economic value for the natural environment, including the marine environment, begins with understanding the many different services that the environment can provide and the contribution these services make to the wellbeing of people. The concept of ecosystem services provides a framework for identifying and quantifying the variety of benefits that we obtain from the environment.

Often, decisions to support economic development negatively affect the functioning or health of ecosystems. Although such decisions are intended to enhance human welfare, they can also reduce the supply of ecosystem services that are critical to human wellbeing and sustainable development. Every time we make a decision that affects the way in which the natural environment functions we are implicitly putting a value on the environment. For example, if we choose to clear mangroves to build a golf course, a trade-off is made between the value of ecosystem services provided by the mangroves and the value of the new development. There is a problem, however, if the decision-maker is not fully aware of the scale of benefits provided by the mangrove. It is possible that such decisions may make society worse instead of better off. Economic valuation of ecosystem services provides information to decision makers on what will be lost or gained by making a decision. Having access to reliable information on the values of ecosystem services facilitates more objective, transparent and informed decision-making.

For most goods or services that we buy, we make decisions based on the price of those items. The price of a good or service is determined by a combination of the cost of providing the good or service (supply) and our preferences for it (demand). The price reflects society's minimum gain in wellbeing, or utility, from producing and consuming one additional unit of that good or service. The price of a good or service therefore reflects its marginal value to society (see Section 3 for an explanation of economic concepts of value). For ecosystem services and the natural environment, there are often no prices that reflect their value, since the services that are provided are 'free', that is they are not traded in markets (e.g. clean air, flood water retention, biodiversity). As a result, we tend not to take the value of ecosystem services into consideration when we make decisions that affect the natural world. The importance of natural assets may be disregarded if they are under-valued and, as a consequence, over-used. When we investigate the implications of projects, such as constructing ports, converting mangroves to tourism developments, or extracting deep-sea minerals, we need to fully understand the environmental as well as the financial implications of the decision whether to proceed. Economic valuation reveals a price for ecosystem services and hence facilitates quantification of the trade-offs involved with decisions that impact natural ecosystems.

Under pressure to respond to immediate problems, but hampered by a lack of high quality information and analysis, decision-makers often have to make quick decisions without full knowledge of the long-term implications of their decisions. Having access to reliable information that describes the costs, values, and risks of environmental change facilitates more objective, more transparent and better informed decision-making. Such information should reduce the pressure on decision-makers by giving them a fuller and more balanced understanding of the economic gains from environmentally sustainable policies, projects and decisions, and the potential losses from unsustainable ones.

Economic valuation of ecosystem services does not provide the 'correct' answer to questions on environmental conservation and management, but it does provide information to facilitate more objective decision-making. It provides a means of measuring the implications of decisions on the provision of ecosystem services, not just to the immediate stakeholders, but also to people affected by environmental change further afield and to future generations.

There are approaches other than economic valuation for quantifying and communicating information on impacts on ecosystem services. For example, bio-physical indicators for ecosystem services may also be used to convey impacts directly to decision makers. The advantage of economic valuation is that impacts are expressed in common units (i.e. money) that can be directly compared and reflect impacts in terms of human welfare.

There are many contexts in which the economic valuation of ecosystem services may be useful, including:

- Raising *awareness* of the value of the environment;
- Revealing the *distribution* of costs and benefits of a project among winners and losers;
- Designing appropriate *regulations, fees or incentives* for use of ecosystem services;
- Calculating potential *returns on investment* for projects that impact the environment;
- Comparing *costs and benefits* of different uses of the environment;
- Calculating values for ecosystem services and natural capital for input into *green accounts*; and
- Calculating environmental *damages* and setting *compensation*.

Because economic valuation is done for a variety of reasons in a variety of contexts, it is difficult to present a uniform framework for economic valuation of ecosystem services. In other words, each new assessment may require a slightly different approach from other studies.

Note also that economic valuation is just one element in a decision process, along with a number of other steps that require expertise beyond the economic domain. For example, the Biodiversity Finance Initiative describes a four-stage process to innovation in conservation finance:

1. Policy and institutional review (PIR, legal and political context);
2. Biodiversity expenditure review (BER, how much are we spending or investing);
3. Financial needs assessment (FNA, what do we need relative to status quo to bridge the finance gap); and
4. Biodiversity finance plan (BFP, what are we going to do and how) prior to implementation.

Legal and public policy expertise are required for the PIR, and accounting and finance for the BER. Ecosystem service valuation can be useful at the FNA stage, but it particularly helps in the BFP stage to prioritize policy actions based on expected return on investment, or the 'business case' for biodiversity investments. Current efforts at climate-change mitigation and adaptation plans take a relatively similar route. WAVES takes a SEEA, or macroeconomic accounting approach, while the Natural Capital Protocol (TEEB) tends to adopt more of a project analysis approach that we broadly adopt and detail below.

A general description of a decision process that involves impacts on the environment includes the following steps:

- problem identification;
- determination of policy or investment options;
- identification of impacts;
- bio-physical assessment of impacts;
- human welfare assessment of impacts;
- valuation;
- estimation of marginal changes in value from impacts;
- policy evaluation; and
- decision-making.

These steps might require inputs from policy analysts, engineers, ecologists, economists and experts in decision support. Although the emphasis of this manual is on economic valuation, these other crucial elements in the decision process should not be ignored.

## 2.2 THE TEEB APPROACH

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

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

This guidance manual focuses on steps 3 and 4 but it is important to stress the importance of the other steps for producing policy-relevant information, in particular the need for stakeholder engagement throughout the process. Stakeholder engagement (e.g. through workshops, interviews, surveys) can be used to determine the specific objectives of an economic valuation study, including which policy issues can be supported by more information about the values of ecosystems goods and services (TEEB Step 1). Stakeholder engagement is also useful in identifying the most relevant ecosystem services to be assessed (TEEB Step 2).

It is also necessary to conduct economic valuation research in partnership with local organisations and government representatives to improve their capacity to analyse and synthesize ecosystem data. Capacity development can include basic training on resource economics concepts, recommendations for modifying or improving data collection and/or on-going monitoring and evaluation of ecosystem service values to achieve sustainable development. To this end, ecosystem service valuation must include the participation of government staff and local resource managers at every opportunity to permanently augment the capacity of country nationals to use ecosystem data and economic valuation in development of policies and resource management decision-making.

# 3 CONCEPTS

## 3.1 ECOSYSTEM SERVICES

Natural ecosystems, including marine ecosystems, have varying attributes and perform various functions. Many of these attributes and functions benefit human activities, communities, and industries. Ecosystem services are the benefits humans receive from the natural attributes and functions of ecosystems. These benefits could be material goods, such as timber, or biological services such as the treatment of human waste and recycling of nutrients. The Millennium Ecosystem Assessment (MA) developed a description and classification system for ecosystem services, shown in Figure 1.

**Provisioning Services**

***Products obtained from ecosystems***

- Food
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

**Regulating Services**

***Benefits obtained from regulation of ecosystem processes***

- Climate regulation
- Disease regulation
- Water regulation
- Water purification

**Cultural Services**

***Non material benefits obtained from ecosystems***

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

**Supporting Services**

*Services necessary for the production of all other ecosystem services*

- Water cycling
- Nutrient cycling
- Primary production

Figure 1. Classification of ecosystem services (MA, 2005)

Focusing on marine and coastal ecosystems in the Pacific, this guidance manual identifies seven key ecosystem services that are addressed in the valuation guidance in Section 5. They are:

- Subsistence seafood
- Commercial seafood
- Minerals and aggregate
- Tourism and recreation
- Coastal protection
- Carbon sequestration
- Environmental research and education

Subsistence and commercial seafood goods are harvested from reefs, lagoons, estuaries, and the open sea. Subsistence food represents the extraction of fish, invertebrates, and other food goods for consumption within the households of those harvesting the food goods. Commercial food represents household-scale and industrial-scale harvesting of fish and invertebrates for sale locally, regionally, or internationally.

Minerals and aggregate can be removed from beaches, reefs, lagoons and the ocean floor. Aggregate (sand and coral) is often used locally in building construction while high-value deep-sea minerals will most likely be sold in global markets.

Minerals and aggregate are considered non-renewable goods; once they are sold or used they will not regenerate naturally over a human lifetime. Both subsistence and commercial food goods are renewable natural goods. The distinction between renewable and non-renewable goods becomes very important when estimating the value of the resource over longer timescales and brings up the question of how to weight benefits to future generations, and the relationship between natural capital stocks and the flow of ecosystem services, which are discussed further in Section 4.2.

Tourists flock to islands and coastal destinations for a number of reasons, including their warm climates, gorgeous beaches, and captivating marine activities. Tourists reveal their appreciation for marine and coastal ecosystems through their choices of activities and their expenditures on those activities. Marine and coastal ecosystems also provide a wealth of opportunities for tourism and recreation by local residents. The value of domestic tourism and recreation may be less visible in markets but nevertheless contributes substantially to human welfare.

Coastal areas, particularly on small atolls, are extremely vulnerable to flooding and erosion from tidal currents and wave action. Mangroves, coral reefs and seagrass beds provide protection from damaging waves and storm surges. This protection is an ecosystem service.

Coastal plants, such as mangroves and seagrasses, remove carbon dioxide from the atmosphere and sequester it in their biomass and the soil. Carbon sequestration is an ecosystem service that benefits the whole world by mitigating climate change.

Marine and coastal ecosystems house remarkable biological diversity that offers unique learning opportunities for students and researchers. Resources dedicated to these activities (scholarships, grants, UN funds, etc.) represent redistribution from donors or funding agencies to researchers and students. Although this redistribution does not represent economic value, it is a benefit to recipients and may be interesting to policy makers. Similarly, internationally funded marine research represents a transfer from donor countries to countries with high marine biodiversity. Research and education regarding marine ecosystems is also expected to produce information and knowledge that may be used to inform better management of marine resources, which has an economic value.

Tourism, coastal protection, and research and education are generally non-extractive services provided by ecosystems.

Marine and coastal ecosystems support a number of other important ecosystem services, including provision of raw materials and important biological and chemical compounds, pollution remediation, oxygen generation, temperature regulation, primary production, and other regulating and supporting ecosystem services. Many of these services are difficult to quantify and value and are not addressed directly in this guidance manual. However, some of these regulating and supporting ecosystem functions contribute to the goods and services that are addressed and therefore their value is embedded in the value of the seven ecosystem services addressed in this guidance manual, in so much as they contribute to the provision of those services.

The appreciation individuals have for ecosystems, even when they are not directly or indirectly using the ecosystem, is also an ecosystem service. Individuals may simply enjoy knowing that an ecosystem exists (*existence value*), or they may appreciate knowing that a resource will be available for future generations (*bequest value*) or for future uses that have not yet been realized (*option value*).

The contribution of ecosystems in building social capital is also recognised as a cultural ecosystem service (Chan et al., 2012). Social capital is broadly defined as the social relationships and cohesion between individuals and communities that encourage reciprocity and exchanges, and enable establishment of common rules, norms and sanctions. Ecosystems may play a role in building social capital by providing space and opportunities for social interaction. Ecosystems may also play a role in establishing and maintaining cultural identity.

Calculating the value of these cultural ecosystem services requires complex surveying and statistical analysis, often in the form of stated preference valuation methods (see Section 4.1), that is beyond the scope of this manual. Guidance on these methods can be found in the resources referenced in Annex I.

# 3.2 ECONOMIC VALUE

*Economic value* refers to quantification of the net benefits humans derive from a good or service, whether or not there is a market and monetary transaction for it. The measurement of economic value is rooted in the neoclassical microeconomic concepts of consumer and producer surplus. Consumer surplus and producer surplus are net measures; they measure the difference between the benefits and the costs of a particular good or service. Consumer surplus is the benefit received by individuals who consume a good or service; producer surplus is the benefit received by businesses, firms, or individuals who sell a good or service.

*Consumer surplus* is the difference between consumers' maximum willingness to pay (WTP) for a service and what they actually pay, i.e. their net benefit from the transaction. Consumer WTP can be represented graphically as a demand curve, which shows the relationship between price and the quantity that consumers want to buy; consumers will demand a good or service if the benefit is at least as high as the price they pay.

*Producer surplus* is the difference between producers' revenue from selling a service and the cost of producing it, i.e., their net benefit from the transaction. The costs of producing a good or service can be represented graphically as a supply curve, which illustrates the relationship between price and the quantity that producers will supply; producers will supply goods and services if they at least cover their costs.

Figure 2 shows the supply (costs) and demand (willingness-to-pay) curves for a hypothetical good or service. The point where the supply and demand curves intersect (D) sets the price (B) and quantity purchased at that price (E). At point E, the benefit to consumers of an additional unit of the good is equal to the cost for producers to provide that next unit, and any additional transactions would not be mutually beneficial. The societal benefit or *value* of this good or service is the sum of the area that lies below the demand curve and above the supply curve; the sum of consumer and producer surplus. Although estimating demand and supply curves for ecosystem services is rarely simple, this explanation of the economic theory of value illustrates the concept of economic value and the process by which the benefits of ecosystem services are quantified.

In the case of many ecosystem services, the quantity available is not determined by 'producers', it is supplied by nature. The quantity of ecosystem service that is 'supplied' is not determined through a market but by decisions regarding ecosystem protection, land use, management, access, etc. The ecosystem service does not have a supply curve in the conventional sense that it represents the quantity of the service that producers are willing to supply at each price. Also, the beneficiaries of many ecosystem services pay nothing. In this case WTP and consumer surplus are equal (i.e. total benefit and net benefit are the same); and there is no producer surplus.

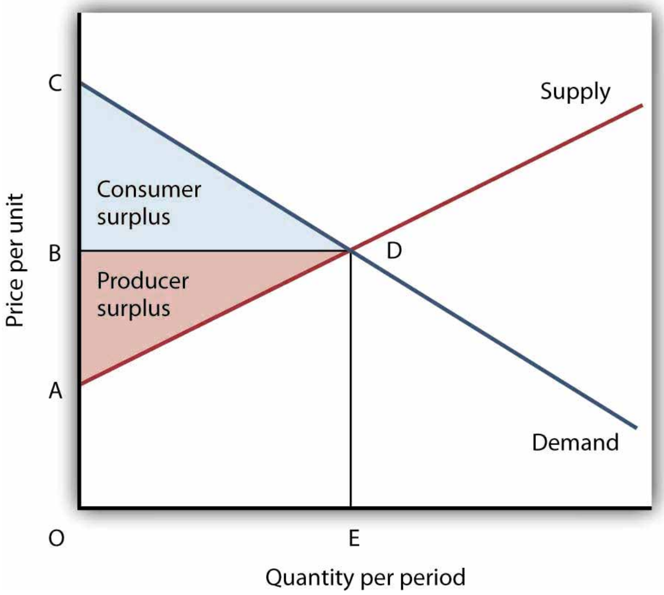



Figure 2. Supply and demand curves for a hypothetical good or service (Rittenberg and Tregarthen, 2009).

## 3.3 TOTAL ECONOMIC VALUE

Total economic value (TEV) is the comprehensive assessment of different sources of utilitarian value from the same resource, including direct use, indirect use, non-use values (Millennium Ecosystem Assessment, 2005). It is important to note that TEV is not the sum of all utility derived from a resource, i.e., it is not the same as "total value". The "total" in TEV emphasizes that there are multiple sources of value that can be derived from an ecosystem. To some extent, there is a correspondence between different sources of utilitarian value (i.e. direct use, indirect use, non-use values) and different categories of ecosystem services (i.e. provisioning, regulating and cultural services). Figure 3 gives examples of different ecosystem services that may contribute to TEV.

In practice, TEV is nearly impossible to estimate because the data required are rarely available. However, the goal of ecosystem service valuation is to get as close to TEV as possible. Section 3 describes the set of methods for calculating economic values for ecosystem services. These methods vary in applicability according to the type of ecosystem service, who receives the benefits, and the nature of the data related to that ecosystem system service.

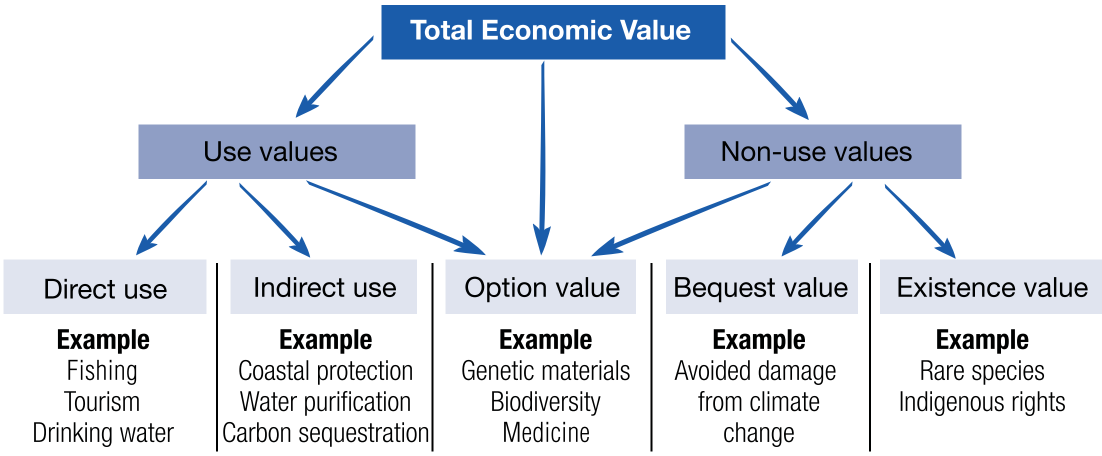



Figure 3. Total economic value (Van Beukering et al., 2007)

## 3.4 EXCHANGE VALUE AND VALUE-ADDED

Economic value should be distinguished from *economic activity* (also known as financial or exchange value), which is a measure of cash flows and is observed in markets[6]. While economic activity from market transactions is often used to calculate economic value, economic activity is not a pure measure of human benefit. Economic activity, however, is an interesting measure. 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 public, civil servants and policy makers. However, economic activity should not be directly compared with economic value. Although both can be represented in dollars per year, they are different measurements of benefits.

*Value-added* is a measure of benefit that lies between economic activity and economic value. Value-added subtracts the costs of all non-labour inputs, but includes the wages paid or income earned by individuals or businesses and the returns attributed to owned capital (such as fishing boats). Gross domestic product (GDP), produced through the system of national accounts (SNA), is a measure of value-added. The UN Statistics Division has recently published guidance for a system of environmental economic accounts (SEEA), which provides an accounting framework that is consistent and can be integrated with the structure, classifications, definitions and accounting rules of the SNA, allowing analysis of changes in natural capital, its contribution to the economy and the impacts of economic activities on it.

6 Analysis of economic activity often focuses on "multiplier effects", that is, the proportion of cash flows from one industry that spill over to other industries through inter-industry links.

# 4 ECONOMIC VALUATION METHODS

## 4.1 VALUATION METHODS

Economic methods used to calculate the value of ecosystem services can be divided into four categories:

1. Revealed preferences of producers
2. Revealed preferences of consumers
3. Replacement and avoided costs
4. Stated preferences

### 1. REVEALED PREFERENCES OF PRODUCERS

Ecosystems, their functions and services, are often inputs to the production of goods and services used or consumed by humans. Measuring the inputs' effect on the quantity and quality of goods and services reveals the value of the input, in this case, the value of the ecosystem. This value represents the contribution made by the ecosystem to the production or provision of the marketed good or service. Since an ecosystem service is usually an un-priced input, a 'shadow' price can be revealed by subtracting all other costs from the price of the final good or service. This is the *net-factor income valuation* method.

This method can be made more sophisticated to measure the marginal or incremental effect that the ecosystem has on the producers' output. This *production function* method requires building a mathematical function to model the production of a good or service. Mangroves, for example, can serve as rearing habitat for young fish. Given data on the extent and density of mangroves, quantities and costs of other inputs (fishing effort) and the quantity and price of fish caught, it is possible to estimate the relationship between mangroves and the productivity of a fishery. The contribution of mangroves to the productivity of the fishery, as a proportion of total fish stock, can then be easily converted to monetary units based on the market value of those fish. Unfortunately, the production function method of valuation requires much more detailed data than is commonly available for many ecosystem services.

### 2. REVEALED PREFERENCES OF CONSUMERS

Where there is no direct market for ecosystem goods and services, individuals often reveal their preferences for the goods and services through related purchases or economic activities. For example, there may not be a fee to surf on a wave, but surfers spend money on fuel, boats, food, travel, and surfboards in order to go surfing. Most of those expenses, if not all, can be attributed to their desire to go surfing. This is a basic example of the *travel costs method,* which estimates the demand for a natural site or activity by calculating the costs individuals willingly incur to visit the site or participate in the activity. The travel cost method is explained in more detail later.

Another way individuals reveal their preferences is through the purchase of composite goods that have varying non-market attributes. This is the hedonic method and is most commonly associated with property or housing purchases. When an individual purchases a home they are paying for the attributes of the home, such as the number of bedrooms and bathrooms. They are also paying for non-market attributes such as a good view or proximity to the beach. Those non-market attributes are often ecosystem services. Given sufficient variation in availability of ecosystem service attributes and sufficient variation in home purchase prices, a demand curve for the ecosystem service attributes can be derived from preferences revealed in property purchases.

## 3. REPLACEMENT AND AVOIDED COSTS

When direct market data for an ecosystem service is not available, the prices of replacement goods or services or the cost savings from avoided damages or restoration measures can serve as proxy values for the ecosystem services. For example, the cost of a sea wall that would provide the same wave protection as a square kilometre of reef is a proxy value for that square kilometre of reef. This is the *replacement costs* method of economic valuation. The *avoided costs or damage costs* method of valuation estimates the probable costs from damages that would occur in the absence of a particular ecosystem. For example, if a reef protects homes and structures from wave damage during a storm, the cost to repair expected damages that would occur without the reef can serve as a proxy value of the reef.

The avoided-costs method may provide a more realistic estimate of the value of an ecosystem than the replacement costs method since a true replacement for the ecosystem is rarely an option. The *avoided-costs* method, however, is more technically difficult because it requires specification of both the probability of damaging events and the contribution an ecosystem makes to averting or diminishing those damages. Note that these two methods calculate a surrogate value, not the true value of the services. This surrogate approximation may under- or over-estimate the true benefits of the ecosystem services, depending on the local conditions and specification of the valuation design.

## 4. STATED PREFERENCES

One way to estimate the value of a good or service is to simply ask individuals how much they would be willing to pay or what they would be willing to trade for the good or service. *Stated preference methods* are most commonly applied to non-marketed goods or services because markets cannot be used to reveal individuals' preferences. The existence value of nature's ecosystems, reserving the opportunity for future uses (*option value*) and the value of nature to future generations (*bequest value*) are non-market ecosystem services. Since there are no markets for these services nor any associated markets that can reveal their value, the only way to estimate their value is to simply ask people what they are worth, using stated preference methods. Estimating the value of an ecosystem service by asking what individuals would be willing to pay for its presence or maintenance is called contingent valuation. Analogously, people could be asked how they would change their behaviour when faced with a hypothetical change. For example, a tourist might choose to visit more (less) frequently or make longer (shorter) trips due to an improvement (deterioration) of environmental quality in a destination. These anticipated behavioural changes can be translated into expected economic effects and the technique that captures these hypothetical changes in demand is called *contingent behaviour.* Asking individuals to make hypothetical trade-offs among different ecosystem services is called *choice modelling*. Both methods ask individuals, via surveys or interviews, to state their preference for the non-market ecosystem service either in monetary terms, or in terms of willingness to trade other goods or services for the non-market ecosystem service in question.

Although difficult to measure, existence, bequest and option values are components of the TEV of an ecosystem. A single individual may only be willing to pay a very small amount for the existence of or option for future use of a resource, but the sum of willingness-to-pay across many thousands of individuals may still represent considerable economic value (Daubert and Young, 1981; Loomis et al., 2000).

# 4.2 OTHER METHODOLOGICAL ISSUES

## TOTAL, AVERAGE AND MARGINAL VALUES

Many economic assessments of marine and coastal ecosystem services aim to produce estimates of the annual TEV. Such information is useful for highlighting the economic importance of marine and coastal ecosystem services to human welfare. In some respects, this information is analogous to the calculation of annual GDP statistics, which involves computing the total exchange value of goods and services produced by an economy in a year.

It can be argued, however, that total valuations of the flow of ecosystem services are not directly useful information to inform policy. Generally, most policy decisions will result in relatively small or marginal changes to the level of ecosystem service provision. Very rarely will a policy decision consider the total loss of an ecosystem service. It may therefore be more useful to provide information on the value of small (marginal) changes in ecosystem service provision. The methods outlined in this manual provide a means to estimate annual values, not marginal values. Researchers are recommended to examine changes in the flow of ecosystem services over time or due to the introduction of new resource management policies in order to estimate marginal values.

It is important to be aware of the distinction between marginal and average values for ecosystem services. The *marginal value* of an ecosystem service is the effect on human wellbeing of a small change in the provision of the service. Marginal value can be thought of as the benefit or cost of the next unit of an ecosystem service, for example, the benefit and cost of one more diver to a dive site or harvest of one more fish from a reef would be marginal values. The *average value* of an ecosystem service is the total value divided by the total quantity of the service provided and consumed. Average values are sometimes used synonymously with marginal values to estimate the impact of small changes to the ecosystem service, but this is theoretically incorrect and in some instances, could be a very inaccurate estimate of changes at the margin.

## TIME

The economic value of an ecosystem service is usually presented either in terms of *annualized value* or *net present value* (NPV). Calculation of an *average* annual value requires specification of a number of years over which the average applies. Net present value is a sum of value expected in future years. A NPV requires specification of the number of future years being considered (e.g. 10 years, 50 years, forever) and a discount rate to represent society's preferences for current benefits over future benefits (Boardman et al., 2006).

The discount rate assumed by profit-seeking businesses should reflect the risk-weighted opportunity cost of financial capital (proxied by the loan rate) and the typical loan repayment period (10–15 years) to ensure a positive return on investment to the business. In contrast, studies estimating the effects of climate-change mitigation actions use relatively low (potentially zero or even negative) social discount rates to account for the anticipated effect of today's decisions on future generations (Stern, 2007). Since the benefits of investments in natural capital are not typically completely captured by the private sector or by this generation, we recommended adopting a social discount rate rather than a private discount rate, although there remains substantial debate over which discount rate is 'correct' (EPA, 2010).

An analysis of discount rates used in Pacific valuation studies showed that the most commonly used rate (mode) is 10% (relatively high) and the average rate is 6.8% (P. Holland, Pers. Comm. 2014). Some countries have a standard discount rate (e.g. 12% in Samoa) used in planning and development cost-benefit analyses. If using a discount rate, analysts should reference common rates used in the country and provide a sensitivity analysis. As with any methodological decision, analysts should state clearly their reasons for choosing a particular rate or range of rates.[7]

## STUDY SCOPE

The guidance provided in this manual is developed from the perspective of quantifying and estimating the value of goods and services from marine and coastal ecosystems within national boundaries and exclusive economic zones (EEZs). Ecosystems within one country may often provide benefits to individuals from another country; this value is included in the valuation methods described in this guide. For example, the majority of commercial tuna fishing in the EEZs of Pacific Island countries is in fact conducted by foreign fleets from China, Japan, the U.S. and others, making these countries stakeholders in Pacific tuna stocks. Economic assessment reports can present the *global* value of goods and services derived from ecosystem functions located within a specific country. This approach yields estimates that are closer to the TEV of ecosystem services. Additional effort is required to describe generally how their value is distributed regionally, nationally, and internationally. A community, regional, or national account of ecosystem service value may best serve economic development and policies for ecosystem services management. The global approach taken here can support international conservation and investment.

The valuation methods presented in Section 5 are intended to yield estimates of the value of ecosystem services from ecosystems in a country at a level of detail and accuracy representative of the limited breadth and acuity of data typically available at a national level in small island developing states.

7 Further guidance on discount rate, time horizon and other dimensions of benefit-cost analysis in the region can be gleaned from, for example, the Asian Development Bank's "Cost-benefit analysis for development: A practical guide." https://www.adb.org/documents/cost-benefit-analysis-development-practical-guide

## DISTRIBUTION

The distribution of economic value is another important methodological topic, and is related to the geographical issues described above. Policy makers and resource managers may be interested in the distribution of benefits of ecosystem services, specifically who benefits from each ecosystem service. Economic value from an ecosystem service rarely accrues evenly to all stakeholders. For example, the economic value of South Pacific tuna may accrue mainly to foreign fishing fleets and foreign consumers. Similarly, the producer surplus value of tourism accrues mainly to resort owners and tourism business operators, many of whom are not residents or nationals of the country providing the resource. The consumer surplus of tourism may also accrue primarily to foreign visitors. Even within a country, some groups will benefit more from ecosystem services than others, depending on where they live and upon which ecosystems their livelihoods depend. When quantifying and valuing each ecosystem service, it is important to describe who receives the economic benefits, producer surplus *and* consumer surplus, of the ecosystem service.

## TRANSFERRING VALUES AND INFORMATION FROM OTHER STUDIES

Referencing previous studies for the country under assessment or other similar countries can be an efficient way to identify, quantify and value marine and coastal ecosystem services. Value transfer is the procedure of estimating the value of an ecosystem service of current policy interest (at a “policy site”) by assigning an existing value estimate for a similar ecosystem elsewhere (at a “study site”). Researchers may choose to borrow methods from previous studies, transfer specific parameters or coefficients, or even extrapolate monetary values from one location to another. Each of these approaches must be interpreted with extreme caution. While it may be appealing to use value transfer to bring attention to the potential order of magnitude of an ecosystem service, there is risk that the transferred values or coefficients will later be quoted as directly representative. Additionally, the process of gathering and analysing data within the study country can be more important to objectives of the assessment than producing dollar values for every ecosystem service. Analysts should focus on explaining that process and analysing data gaps before turning to other studies for representational numbers. However, if an ecosystem service is identified as important but no acceptable data can be found to quantify or value the service, careful use of value transfer could help fill data gaps and permit acceptably accurate estimates of the magnitude of ecosystem benefits. We recommend that study sites and policy sites should be similar in terms of the characteristics of the ecosystem and beneficiaries to ensure that transferred values are reasonably accurate. Analysts should control for differences in characteristics between study and policy sites. (See Brander, 2013, for detailed guidance on conducting value transfer for ecosystem services). Jungwiwattanaporn and Pendleton (2014) provide a review of the ecosystem services literature in the Pacific and may be referenced for relevant methods, coefficients and values.

## UNCERTAINTY AND SENSITIVITY ANALYSIS

Estimates of ecosystem service values may differ significantly from the actual value of the ecosystem service under consideration, particularly if data is unreliable. Similarly, market prices may not accurately reflect social benefits and costs of a transaction for a variety of reasons, including, for example, ‘thin’ or incomplete markets, joint and/or public goods attributes of the ecosystem service, externalities in production or consumption, ability to pay and market power. Ecosystem service value estimates may be inaccurate for a number of reasons. Sources of uncertainty include incomplete or inaccurate underlying data on the quantity and quality of ecosystem service provision, prices of services, costs of production, and other variables used in estimation of values. Uncertainty may also be introduced in the use of value transfer methods if the underlying “study site” valuation studies are themselves inaccurate.

The magnitude of uncertainty should to be quantified and communicated for an understanding of the robustness of the values provided. Decision makers can then assess whether the information is sufficiently precise to be considered in making a decision. A balance has to be struck between presenting too little information on the level of uncertainty (e.g. giving the impression of high certainty for a central estimate) and too much information that cannot be effectively understood or synthesized (e.g. a table of results for an extensive sensitivity analysis).

Sensitivity analysis can be used to show how estimated values change as parameters, data inputs and assumptions used in the estimation change. A sensitivity analysis involves systematically varying (within plausible ranges) the uncertain inputs to an estimated value to assess how sensitive the results are to those changes. Joint sensitivity analysis (varying more than one parameter at a time) is sometimes also useful if possible changes in parameters are not independent of each other. In this case, scenarios can be developed that describe how multiple parameters might change in combination.

For each ecosystem service value estimate it is necessary to provide a qualitative discussion of the quality of the underlying data and identify possible inaccuracies. Identify and discuss the possible direction of the effect on the estimated value (whether the estimate is likely to be an under- or over-estimate as a result of an identified uncertainty); where possible, provide a quantitative assessment of the magnitude of uncertainty in the estimated value by using a sensitivity analysis and/or reporting a range of values.

## SUPPORTING OR INTERMEDIATE ECOSYSTEM SERVICES AND "DOUBLE-COUNTING"

Some ecosystem functions do not directly benefit humans, but may be instrumental in supporting the provision of ecosystem services. Fundamental ecosystem functions such as photosynthesis, nutrient cycling, soil and sand formation and other so-called *supporting* ecosystem services are intermediate services to many final ecosystem services. Their value, however, is carried over into the final ecosystem services. For example, many microscopic processes occur within a coral reef that support the health and growth of the bright corals and fish that tourists travel to see. The value of the minute processes is a component of the tourists' WTP to dive on that reef, even if they are unaware of these processes. To avoid double-counting the value of supporting ecosystem services, ecosystem service valuation should focus on the final human benefits coming from the end-products of ecosystem functions (Boyd and Banzhaf, 2007; Fisher et al., 2009).

## COMPLEMENTARY ECOSYSTEM SERVICES AND TRADE-OFFS

Some ecosystem services are complementary with other ecosystem services and others are not. For example, the same reef that offers great snorkelling opportunities may provide protection from coastal erosion and flooding. Other activities, such as reef fishing or aggregate mining may detract from snorkelling opportunities. In this case the ecosystem services are competing. Competing ecosystem services should be identified in national reports to prevent inaccurate summation of their value.

## EXISTING AND POTENTIAL ECOSYSTEM SERVICES

Another methodological question is whether to measure potential economic value or existing economic value. For *provisioning* services, such as subsistence and commercial fishing, value could represent current harvest rates, maximum sustainable harvest rates, or optimal harvest rates (based on maximizing utility or some collection of wellbeing parameters or resource exploitation constraints). We recommend that ecosystem service assessments calculate the current economic value (e.g. at current harvest rates), and then reference this value, when relevant, to optimal or potential future values. It should be made clear whether an ecosystem service value represents sustainable or unsustainable resource use, in so far as this can be determined. This approach is particularly useful to policy makers and resource managers because it estimates whether resources are currently being under- or over-exploited and therefore whether or not net social benefit could be improved with changes to resource management. If an ecosystem is being unsustainably exploited, the average annual value may be high, but decreasing year after year. A net present value calculation, looking ahead many years, will reveal the potential long-term benefits of sustainable resource use.

The distinction between potential and existing economic value is also relevant to cultural ecosystem services such as tourism. For example, Kiritimati Island in the Line Island group of Kiribati is surrounded by interesting scuba diving sites, yet very few divers come to Kiritimati because of the absence of diving infrastructure (dive masters, tanks, gear, and dive boats). The value of the ecosystem service (diving) is constrained by the lack of infrastructure, not by an ecological constraint. If dive infrastructure were developed, the value of the tourism ecosystem service could be much higher in Kiribati. This "potential future service" is of great interest to resource managers and decision makers. Potential ecosystem services can be examined by developing plausible scenarios of future uses, and by referencing comparable sites with similar attributes (see Jungwiwattanaporn and Pendleton, 2014). A stakeholder engagement process may help to identify development initiatives and/or pending policies that may reveal probable or plausible changes to resource use. Analysts should link any analysis of resource-use scenarios to specific policies, government or private industry initiatives, or discussions with ecosystem service stakeholders.

# 5 GUIDANCE ON VALUATION OF MARINE AND COASTAL ECOSYSTEM SERVICES

This section describes mathematical methods and data requirements for estimating the value of the seven marine and coastal ecosystem services outlined in Section 3.1. Since this guidance manual focuses on the estimation of annual values of ecosystem services, the terms in all the equations here refer to annual averages.

## 5.1 FISHING

By providing appropriate food and habitat conditions, mangrove, seagrass, reef, and open sea ecosystems support the growth and reproduction of a range of fish and invertebrate species that become food for humans. The productivity of a fishery depends on the functions provided by one or more of these ecosystems. Fishing can be quantified by a variety of metrics, including the number of fisherman, number of boats, kilograms of fish caught, or the quantity of fish in household diets. These numbers do not represent economic value, but they may serve as an important measure of the magnitude of the ecosystem service. Here we present a way to estimate the annual value of seafood harvests to fishermen and fisherwomen or fishing businesses.

The annual value to fishers from a fishery is, in most basic interpretation, the market value of the seafood harvested (or its protein equivalent) in a given year, minus the costs of harvesting. The basic valuation approach is illustrated by equation 1:

$$\text{Fisher Value} = \left(\text{Harvest}_{kg} \cdot \text{Price of Fish}_{\frac{\$}{kg}}\right) - \text{Harvest Costs}_{\$}$$

Equation 1

The precise nature of the value estimate depends on what are considered "harvest costs". If only variable input costs (such as fishing gear and fuel) are subtracted, the result is called the *value-added* (this includes wages paid and does not subtract the opportunity costs of choosing to fish rather than work elsewhere). Wages paid to hired fishermen could be considered a cost to a fishing business, and the choice to fish rather than find other work is an opportunity cost to those who fish. Subtracting wages or imputed wages (opportunity costs) and capital costs (e.g. depreciation of boats), results in an estimate of producer surplus.

If the marine ecosystems in the study area are responsible for 100% of fishery productivity, this equation represents the value of the ecosystem service (the returns to labour, capital, and the resource). In the case of most reef fish, which are born and raised within reef habitat, this is a fair assumption. Pelagic fish, however, migrate great distances throughout their lives, so the area in which they are harvested (caught) is only partially responsible for their growth and reproduction. For pelagic fish, the assumption made is that the marine ecosystem in which they are caught is 100% responsible for the value of the fish. This means that the harvest of pelagic fish within a country's EEZ is proportional to the contribution of the ecosystem functions (within that EEZ) to the growth and reproduction of all pelagic fish in the regional fishery.

The economic value provided by the harvest of fish and invertebrates can be split into two categories: subsistence fishing and commercial fishing. There is some difference in the economic methods required to calculate the value of these two ecosystem services, so they are presented separately below. The value of recreational fishing is addressed under "Tourism and recreation" in Section 5.3.

## SUBSISTENCE FISHING

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Reef, mangrove, and other benthic and pelagic near-shore fish and invertebrate habitats | Clean, healthy habitat and food that facilitate the reproduction, rearing, and growth of edible marine organisms | Fish and invertebrates caught and consumed by fishing households |

Subsistence fishing refers to fishing or harvesting of seafood that is consumed, given, or exchanged by fishermen without any monetary transaction. In Pacific Island Countries and Territories (PICTs), particularly in rural coastal areas, subsistence fishing contributes significantly to household diets and therefore has substantial economic value (Gillett, 2009). The value of subsistence fishing can be calculated by subtracting the costs of fishing from either the expense of procuring an equivalent protein food or the average market price of fish. The aim is to understand the benefits of time spent fishing in financial terms. The average market price of fish is the most obvious substitute or replacement for caught fish. However, it may be that people tend to substitute some other form of protein for fish when they do not catch enough to feed themselves and their families (e.g., canned tuna or canned corned beef). The residual (net) value of subsistence fishing is subsistence surplus; since the producer and consumer are one and the same, it is neither a true producer nor consumer surplus.

$$\text{Subsistence Surplus} = \left(\text{Subsistence Harvest}_{kg} \bullet \text{Price Protein Equiv.}_{\frac{\$}{kg}}\right) - \text{Harvest Costs}_{\$}$$

Equation 2

Using the ‘alternative protein’ approach likely provides a minimum value because the human welfare associated with eating fresh seafood is usually greater than eating the “price protein equivalent” which may be canned meat. The average market price approach typically provides a maximum value because fishers may not be able to sell their subsistence harvest at average market prices nor may they choose to purchase those same seafood species if they did not catch them.

### **BOX 1** CALCULATING NET BENEFITS WHEN THERE IS BOTH SUBSISTENCE AND COMMERCIAL FISHING EFFORT

Total annual fish harvest is a sum of the catch from a variety of different fishing methods or techniques. Since many fishermen are not fishing exclusively for consumption or exclusively for sale at market, the subsistence harvest is likely some fraction of the total harvest. This scenario is reflected in equation 2.1.

$$\text{Subsistence Harvest} = \sum \text{Effort}_i \bullet \text{CPUE}_i \bullet \text{Proportion Subsistence}$$

Equation 2.1

Where $Effort_i$ refers to hours per fishing method and *CPUEi* is the catch per unit of effort for that method *i*. This extraction of the harvest process breaks down the total subsistence harvest into smaller components. These components are discrete data values: *effort* in hours, *catch-per-unit-effort* in kg/hour, and a subsistence coefficient (*Proportion subsistence*, or *SC*) that is less than or equal to 1. To convert the annual total harvest (kg) into a dollar value ($), the harvest is multiplied by the typical price of fish ($/kg) or equivalent protein food (*PE*).

Costs of harvest can be similarly deconstructed. Harvest costs also vary per fishing method, and are therefore represented by the term $\Sigma C_{i(\$)}$. This leads to the following formal equation for the value of subsistence fishing.

$$\text{Subsistence Surplus} = \left(\sum E_{i(hrs)} \bullet \text{CPUE}_{i\left(\frac{kg}{hr}\right)} \bullet \text{SC}\right) \bullet \left(\text{PE}_{\left(\frac{\$}{kg}\right)}\right) - \sum C_{i(\$)}$$

Equation 2.2

Note that the components of subsistence fishing harvest have been parsed out in Eq. 2.2 in this box, but this is essentially the same as Eq. 2 in the text.

## BOX 2 SUBSISTENCE FISHING WORKED EXAMPLE: TONGA

Data on the quantity of subsistence harvest in Tonga, the price of fish (replacement cost) and the cost of subsistence harvest are given below. Using Equation 2, subsistence surplus is calculated as:

$$\text{Subsistence surplus} = (733{,}000 \times 4.62) - 338{,}400 = \text{US\$}3{,}045{,}600$$

Annual value of subsistence fishing in Tonga

| | Value | Source |
|---|---|---|
| Harvest (tonnes) | 733 | Tonga household income and expenditure survey, 2009 |
| Average Market Price (US$/kg) | 4.62 | Market survey, 2014 |
| Gross value (US$) | 3,384,000 | |
| Harvest costs (US$) | 338,400 | Tonga Statistics Department |
| Subsistence surplus (US$) | 3,045,600 | |

Source: Salcone et al. (2015)

# COMMERCIAL FISHING

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Primarily open ocean and deep-sea areas, some supporting services from reefs | Habitat and food that facilitate the reproduction, rearing, and growth of edible fish, mainly pelagic species | Fish caught and sold commercially in local and global markets |

Commercial fishing refers to fishing or harvesting of seafood that is then sold or exchanged via a monetary transaction. Commercial fishing is a large component of many Pacific island economies. The value of commercial fishing is a sum of the value to businesses and individuals selling fish and the value to individuals purchasing and eating fish. The producer surplus can be calculated by subtracting the costs of fishing from the total revenue of fishermen.

$$\text{Producer surplus} = \text{Commercial Fishing Revenue}_{\$} - \text{Commercial Fishing Costs}_{\$}$$

Equation 3

Again, subtracting only the intermediate input costs, such as gear and fuel, results in an estimate of the *value-added of the ecosystem service.* To determine the producer surplus, wages and payments to capital (i.e. rent or depreciation of boats) must be subtracted from the value-added.

This could be further broken down by fishing type in the same way as the subsistence surplus. Revenue is the quantity of fish harvested times the market value of those fish (*P*).

$$\text{Producer surplus}_{(\$)} = \left( \sum E_{i(hrs)} \cdot CPUE_{i\left(\frac{kg}{hr}\right)} \cdot P_{i\left(\frac{\$}{kg}\right)} \right) - \sum C_{i(\$)}$$

Equation 4

If fishing method, indicated by subscript *i,* refers to a particular fish species, the same subscript can be used to indicate the price per kilogram of that species. If the fishing method collects many different species, the quantity of each species harvested is multiplied by the unique price that species will fetch in market.

Costs include input costs, labour costs, capital costs, and fees or fishing licenses[8]. Input costs, also called *intermediate costs,* include fuel, bait, and nets. Labour costs can be actual wages paid, or in the case of self-employed fishers, the *opportunity cost of labour*. The opportunity cost of labour is the income or wages a fisher could earn by working the next-best available job. A country's minimum wage is often used to estimate the opportunity costs of fishing. The largest capital cost associated with commercial fishing is typically a boat. The annual capital cost of a boat could be the market rental rate for a boat, an annualized estimate of depreciation, or most simply, the total costs of the boat divided by the number of years in the boat's functional life.

The producer surplus calculated by Eq. 4 is the value of the fishery to the fishermen and fishing fleets. In order to calculate this value for a particular country's resources, data must represent the total catch by fish type harvested from *within the territorial waters* of that country. The value of the total catch (by all fleets) within a country's EEZ is the *global* producer value of that country's commercial fish resources. Because a large amount of fishing is conducted by foreign fishing fleets, much of this value is lost or "leaked" to foreign firms. Domestic producer surplus or local economic activity from fishing may be a more interesting measure for policy makers. Domestic producer surplus is the profits earned by national fishing fleets. Domestic economic activity includes wages paid to local fisherman, expenditures on local inputs, and earnings from market vendors. Each of these measures is a useful way to quantify the value of the commercial fishery.

Commercial fishing also yields economic benefit to consumers, those who purchase and eat fish. The consumer surplus of commercial fishing is the difference between the maximum that consumers are willing to pay for fish and real market prices. In other words, consumer surplus is the total demand (WTP) minus what is actually paid (price x quantity). Graphically, this is the area under the demand curve, above the market price (see Figure 2, Section 3.2). While the market price and quantity of fish sold to different countries is generally available, a demand curve might not be. However, a simple linear demand curve could be estimated from price elasticity[9], a total quantity, and an average price. Analysts can then estimate the area under the demand curve and subtract the consumer costs (total quantity times average price) to estimate the consumer surplus. With sufficient data this could be estimated for a variety of key markets where the fish is sold.

## BOX 3 COMMERCIAL FISHING WORKED EXAMPLE: FIJI

Data on the revenue and costs of inshore artisanal commercial fisheries in Fiji are average revenues and costs per household obtained from a household survey (O'Garra, 2007). To extrapolate the estimated value-added per household to the national level, it is multiplied by the number of licensed artisanal fishers (Fiji Fisheries Department, 2014). Based on Eq. 3, the annual value-added from artisanal fisheries is calculated as:

$$\text{Value-added from artisanal fisheries} = (12{,}847 - 601) \times 2{,}538 = 31{,}080{,}348$$

Annual value of artisanal fishing in Fiji

| | Value | Source |
|---|---|---|
| Gross revenue per household | 12,847 | O'Garra (2007) |
| Cost per household | 601 | O'Garra (2007) |
| Number of licensed artisanal fishers | 2,538 | Fiji Fisheries Department (2014) |
| Value-added | 31,080,348 | |

Source: Gonzales et al. (2015)

8 Fishing licenses and fees could be fixed or variable. A seasonal license would be considered a fixed cost; fees based on harvest quantity are variable costs.

9 The elasticity is the anticipated percentage change in the quantity demanded due to a percentage change in the price. The relationship is negative; when prices go up, quantity demanded goes down. If the percentage change in quantity is less than the percentage change in price, demand is relatively inflexible, or 'inelastic'. If the percentage change in quantity is greater than the percentage change in price, demand is said to be 'elastic' or more flexible to changes in price. Typically, goods for which there are many alternatives, or substitutes, have more elastic demand than those that do not. Demand is more elastic in the long term, when investments and other adjustments can take place, than in the shorter term.

## **5.2** MINERALS AND MINING

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Beach, reef, and deep sea floor | Accumulation of minerals, coral, sand, gravel, rock | Minerals for electrical and technical uses; sand and aggregate for use as building material |

Sand and gravel used in concrete, roads and cinder block can be mined from beaches and lagoons. Concentrated mineral deposits can be found on the deep sea floor. Both goods are generally considered non-renewable within human lifetimes, but their extraction may offer significant income and tax revenue for island countries. The producer surplus of these goods is calculated as the total revenue from sale of the materials, minus the costs of extraction. The consumer surplus may also be significant, given that aggregate is an important construction material and that minerals are important to the production of luxury goods, such as mobile phones and flat-screen televisions. Mining, however, can also have significant negative externalities. *Negative externalities* are un-priced costs or harms that accrue outside of the mining industry. For example, if sand mining on a beach induces salt-water intrusion that contaminates the groundwater supply to local villages, the loss of clean groundwater is a negative externality of beach mining. Coastal erosion and siltation of reefs are other potential costs of aggregate mining; thus, mining may compete with other ecosystem services such as coastal protection or fishing. To accurately represent the economic value of mining, the cost of externalities must be subtracted from the mining profit and consumer surplus. Estimating the value of these costs is therefore the crux of valuing this ecosystem service. McKenzie et al. (2006) provide an example of how the external costs of aggregate have been estimated for the Majuro Atoll in the Republic of the Marshall Islands. They use two valuation methods: preventative expenditures and damage costs of erosion.

Provided the costs and externalities can be determined, calculating the producer surplus of aggregate mining is a relatively straightforward process. For a given year, the producer surplus is simply the price times the quantity, minus the extraction costs and the costs of externalities.

$$\text{Producer surplus}_{(\$)} = \left(Q_{(kg)} \cdot P\left(\tfrac{\$}{kg}\right)\right) - \text{Costs}_{\$} - \text{Externalities}_{\$}$$

Equation 5

The "socially optimal" annual rate of extraction will be that which averages the annual marginal benefits of extraction over future years, subject to a discount rate. The ecosystem service will "run out" when either the material is exhausted, or when the cost of extraction exceeds the marginal benefit of the material (the price)[10].

Deep-sea minerals (DSMs) are quite different from aggregate mining because so little is known about the reserves, costs of extraction, or environmental externalities. Very few deep-sea mineral operations have begun; most operations remain in the exploration phase. For example, the only deep-sea mining currently occurring in the Pacific is in Papua New Guinea by Nautilus Minerals, a Canadian mining firm. Nautilus has conducted extensive and detailed environmental impact assessments and feasibility studies, which may currently be the best reference for deep-sea mining costs. Because so little deep-sea mining has been carried out, it is safe to assume that there is a high risk to investment. However, because some minerals have become increasingly scarce in recent years (copper, for example), it is also safe to assume that there will be increasing interest in deep-sea mining. As with land-based mining, Pacific island countries could stand to earn substantial royalties on these activities, and mineral extraction may offer significant producer and consumer surplus benefits (SPC, 2013). Although the environmental externalities are largely unknown, it is reasonable to expect that deep-sea mining may be less harmful than land-based mining externalities. In addition, sea-floor massive sulphide deposits that occur at vents in the ocean floor may be renewable within a human timescale, creating the potential for "sustainable" sea-bed mining. More information about costs and benefits of mining can be obtained from SPC (2013) and McKenzie et al. (2006).

Since the extraction costs and externalities are largely unknown, a true valuation of DSMs is not yet possible. However, analysts should attempt to quantify the magnitude of this ecosystem service by presenting data that describes the location, quantity, and quality of DSM reserves. Some countries currently receive revenue from mineral exploration licenses. Although these licenses represent a cost to mining companies, the revenue is an economic benefit to the licensing countries.

10 This method assumes that mining is a competitive industry and that no individual firm in the region can affect the market price of sand or minerals, and that the global reserves are not scarce enough to put upward pressure on world prices in the short term.

## BOX 4 AGGREGATE MINING WORKED EXAMPLE: VANUATU

Data on the quantity, price and cost of aggregate mining in Vanuatu are given below. Based on Eq. 5, value-added[11] from aggregate mining is calculated as:

Producer surplus = (15,250 x 45) – (15,250 x 34) = 171,563

Annual value of aggregate mining in Vanuatu

| | Units | Value | Source |
|---|---|---|---|
| Quantity | $m^3$ | 15,250 | Department of Geology and Mines |
| Price | US$/$m^3$ | 45 | Greer Consulting Services 2007 |
| Cost | US$/$m^3$ | 34 | Greer Consulting Services 2007 |
| Gross revenue | US$ | 686,250 | |
| Total cost | US$ | 514,688 | |
| Value-added | US$ | 171,563 | |

Source: Pascal et al. (2015)

# 5.3 TOURISM AND RECREATION

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Beach, coral reef, charismatic ocean species | Health and abundance of charismatic species and naturally beautiful areas | Wide range of tourism activities, including diving, snorkelling, recreational fishing, and general coastal recreation |

Many island economies are heavily reliant on international tourism. The economic benefits of international tourism can be illustrated by comparing the gross national income (GNI) per capita of countries with well-developed tourism industries, such as Fiji and Vanuatu, to countries with minimally developed tourism sectors, such as Kiribati and the Solomon Islands. The GNI per capita[12] of the touristic countries is $4,690 and $4,300, respectively, while in the less touristic countries GNI is $3,870 and $2,130 (World Bank, 2012). Clearly this is not a rigorous economic analysis of the marginal economic benefits of tourism, but nonetheless, the comparison motivates analysis of the tourism value of marine and coastal ecosystems. This section explains how to quantify local and international tourism and recreation services provided by marine and coastal ecosystems.

Marine and coastal ecosystems offer an extensive variety of passive and active recreational activities. Recreational activities provided by the sea, reef, and beach include a wide range of pursuits including swimming, diving, snorkelling, charter fishing, fishing from the shore, recreational gleaning, kayaking, surfing, free-diving, beach activities and passive appreciation of beautiful coastal vistas. These activities can be collectively defined *marine and coastal tourism and recreation.*

Some recreational activities involve marketed services, such as diving and charter fishing, and have observable market prices. Other activities are generally not traded in markets, such as swimming, beach activities, and appreciation of coastal views. This has implications for the valuation methods appropriate to each case and the extent to which values can be estimated without collection of primary data. In particular, the estimation of consumer surplus from non-market recreation activities by local residents would require the use of stated preference survey methods, which is beyond the scope of this guidance manual. Such activities, however, may have high economic value. It is therefore important that all relevant tourist and recreational activities be identified, described qualitatively, and quantified before valuation, where possible.

11 This calculation yields value-added and not producer surplus because it does not subtract depreciation of capital, only input costs.

12 Gross national income (GNI) is represented in terms of purchasing power parity, which corrects for differences in costs of living.

The beneficiaries of marine and coastal tourism and recreation services are diverse and can be from nearby communities, other parts of the country (domestic tourists) or from distant countries (international tourists). Local recreationists may participate in different activities and hold different values than international tourists. The methods for estimating tourism and recreation values are generally similar regardless of the beneficiary, so the methods here do not distinguish between beneficiary groups. It is important to explicitly identify, collect data, and estimate values for different beneficiary groups where relevant.

The benefits from marine and coastal tourism accrue to tourism providers (producers) and tourists (consumers). The producer surplus of a tourism activity is the service providers' revenue from tourists' expenditures, minus the costs of providing the service. Producer surplus is represented by the profit (revenue, net of all costs) of tourism providers. Because many tourism providers are foreign nationals and because there are often limited investment opportunities in small island states, much of these profits may be remitted or invested overseas. Therefore, domestic economic activity from tourism may be a more interesting measure for policy makers. Domestic economic activity includes wages paid to staff and expenditures on local inputs. Both of these measures would be useful ways to quantify tourism ecosystem services.

Reefs, beaches, and ocean biodiversity all contribute, to varying degrees, to the marketability of tourism activities. We refer to the degree of association between marine and coastal ecosystems and different tourist activities as the *ecosystem contribution factor* (ECF). The producer surplus value of the ecosystem services is calculated by multiplying the ECF by the difference between the tourists' expenditures and the tourism industry's costs. This is most clearly illustrated with a simple linear equation.

$$\text{Producer surplus}_{(\$)} = (\text{Total Tourism Revenue}_{\$} - \text{Tourism Industry Costs}_{\$}) \bullet \text{ECF}$$

Equation 6

The precise ECF for each tourist activity is difficult to determine. Regression analysis could be used to determine the ECF from a robust data set acquired from a detailed survey of a statistically representative sample of tourists. The survey would need to reveal what motivates tourists' travel, lodging, and activities. Alternatively, analysis of advertising images has been used to estimate how various opportunities and amenities contribute to tourist decisions. For example, if underwater pictures of reefs and reef fish make up 60% of advertising images for a resort, an ECF of 60% for reefs is assumed for visitors to that resort. Clearly this is a rough approximation of the ECF, but the results may be sufficiently accurate in many decision-making contexts. For some tourist expenditures, such as snorkelling, it may be safe to assume the ECF of healthy reefs and clean waters is 100%, meaning that the ecosystem is the only factor contributing to the tourists' decision to go snorkelling. A third method is to rely on expert opinions on the ECF for each tourism activity. For example, an opinion about how much different ecosystems and ecosystem functions contribute to tourism expenditures could be sought from a focus group of tourism providers and marine ecologists.

Producer surplus should be broken down into smaller categories by type of tourism activity, as data allows. For example, if there are detailed data on different types of dive trips, the producer surplus for each type of dive trip ($i$) can be summed as shown in equation 7.

$$\text{PS Diving} = \sum (\#\ \text{dives}_i \bullet \text{Price per Dive}_{\$} - \text{Costs per Dive}_{\$}) \bullet \text{ECF}_i$$

Equation 7

Where subscript $i$ is the specific type of dive trip. The number of different tourism categories (i Max = n) will depend on the visitor data available from the tourism industry and the tourism ministry. Costs would include variable costs such as fuel and dive instructor wages, and a portion of capital costs such as dive boats and scuba gear.

The total producer surplus from the tourism ecosystem service is the sum of the producer surplus from each tourism activity related to marine and coastal ecosystems.

The consumer surplus enjoyed by tourists is the difference between what they would be willing to pay for activities, travel, and lodging, and what they actually paid. For example, if a tourist is willing to pay up to $200 for a two-tank dive, but the dive operator only charges $150, the consumer surplus is $50. The best way to reveal the consumer surplus of tourist expenditures is via an individual travel cost model. This is a three-step process: (1) collect information about tourists' expenditures, travel distance, duration of stay, reasons for traveling, and demographic information; (2) estimate a regression to fit these data; and (3) use the results of the regression coefficients to create a demand function that represents the behaviour of an 'average' tourist. The consumer surplus from this average visitor can be multiplied by the total number of tourists to estimate the total consumer surplus.

If individual data cannot be captured, a zonal travel cost model can be used. With this approach, travel costs are estimated from different distances or 'zones'; the variation between zones and the number of visitors from each zone can be used to estimate a demand curve. This method, however, assumes that preferences of visitors from each zone are homogeneous. One difficulty with the travel costs method is determining how much of individuals' capital costs (such as boats or surfboards) should be included with their variable costs (fuel or travel time) for a given visit or number of visits.

The total value of an ecosystem service is the sum of the producer surplus and consumer surplus, but due to the data requirements, one or the other is often neglected. If neither measure can be estimated, analysts should explain why, estimate whether the quantification of the tourism ecosystem service used is most likely an over- or under-estimate of the true economic value, and share examples of value estimates from other studies to fill in the gaps.

It is also important for analysts to discuss who receives producer and consumer surplus. Planners and policy makers are likely to be interested in the distribution of benefits from this ecosystem service including how it is related to GDP and the national balance of payments. Although employment (labour) is a cost that is subtracted from producer surplus, employment and labour expenditures may be considered important benefits and therefore should be reported alongside surplus measures when available.

## **BOX 5** TOURISM WORKED EXAMPLE: TONGA

Data on tourism total revenue, intermediate costs and ecosystem contribution factor for Tonga are given below. The intermediate costs of providing tourism services in Tonga are computed using an estimate of the added value of tourism of 25% from a study in Guam (van Beukering et al., 2007). Gross tourism value in Tonga is computed as:

$$\text{Total cost} = 16{,}279{,}777 \times 0.25 = 12{,}209{,}833$$

Using equation 6, tourism value-added from coastal ecosystems is calculated as:

$$\text{Value-added} = (16{,}279{,}777 - 12{,}209{,}833) \times 0.3 = \text{US\\$ } 1{,}220{,}983$$

ANNUAL VALUE OF TOURISM IN TONGA

| | Unit | Value | Source |
|---|---|---|---|
| Total revenue | US$ | 16,279,777 | Tonga tourism statistics (2013) |
| Value-added | % | 25 | van Beukering et al. (2007) |
| Total cost | US$ | 12,209,833 | |
| Ecosystem contribution factor | % | 30 | Ministry of Commerce, Tourism and Labour (2013) |
| Ecosystem value-added | US$ | 1,220,983 | |

Source: Salcone et al. (2015)

# 5.4 COASTAL PROTECTION

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Coral reef, mangrove, and seagrass | Capture wave energy, secure sea-floor materials, accumulate sand | Protection of coastal areas from erosion and flooding |

Mangroves, reefs, and seagrass ecosystems mitigate coastal erosion from waves and provide a buffer against tidal inundation. The value of this ecosystem service is the savings from damages avoided or the cost of replacing the natural ecosystems with man-made equivalents. These values are calculated using the *avoided damage costs method.*

The *avoided damage costs* method considers different types of avoided costs, that is, the cost of property damage that would likely occur in the absence of the natural ecosystems. The damage costs method requires (1) determination of the extent of protection provided by natural ecosystems, (2) the population, property, and human infrastructure at risk from erosion or flood damage, and (3) the probability of damages given the estimated frequency of flood or erosion events. The value of the natural ecosystems is the costs from expected damages to homes, businesses, agriculture, or public infrastructure that are avoided because of the presence of natural ecosystems. Such methods have been used to value the coastal protection ecosystem service of Caribbean (Burke et al., 2008) and New Caledonian reefs (Pascal, 2010).

The valuation of coastal protection against storm surges takes the following steps:

1. *Identify areas at risk from coastal flooding events.* Areas at risk to coastal flooding are identified as sites that have a lower elevation than the maximum wave height at high tide and up to 1 km inland (Kench and Brander, 2006; Das and Vincent, 2009).
2. *Assess the level of coastal protection for each segment of coast using a coastal protection index (CPI).* A CPI is a qualitative assessment of the multiple factors determining the overall level of coastal protection. The CPI used in this analysis includes seven factors, listed in Table 5. Each factor is given a score in the range 1–5, with 1 indicating no protection and 5 very strong protection. The maximum total score is 35 and the minimum is 7. The index is standardised to values between 0.2 and 1 by dividing the sum of factor scores by 35.
3. *Identify assets at risk.* Assets at risk of flooding can include people, buildings, transport and communication infrastructure, vehicles, livestock and crops.
4. *Estimate damage costs in the event of a flood.* Damage costs to buildings in the event of coastal flooding are calculated as a fixed percentage of total construction costs. This approximates the cost of repairing a building if it is damaged by flood.
5. *Estimate the probability of a storm surge.* The probability of a storm surge occurring is used to annualize the value of damage costs. The spatial and temporal occurrence and severity of past events can be used to predict potential tropical cyclones that may affect the study zone in the future.13
6. *Compute the expected annual damage due to coastal flooding.* The expected annual damage is a function of the frequency of storm surges, the level of coastal protection (represented by the CPI) and the value of assets at risk. A general equation for expected annual damage costs due to coastal flooding is:

$$D_t = P_t \cdot (1 - CPI) \cdot (A \cdot C \cdot DF)$$

Equation 8

where:

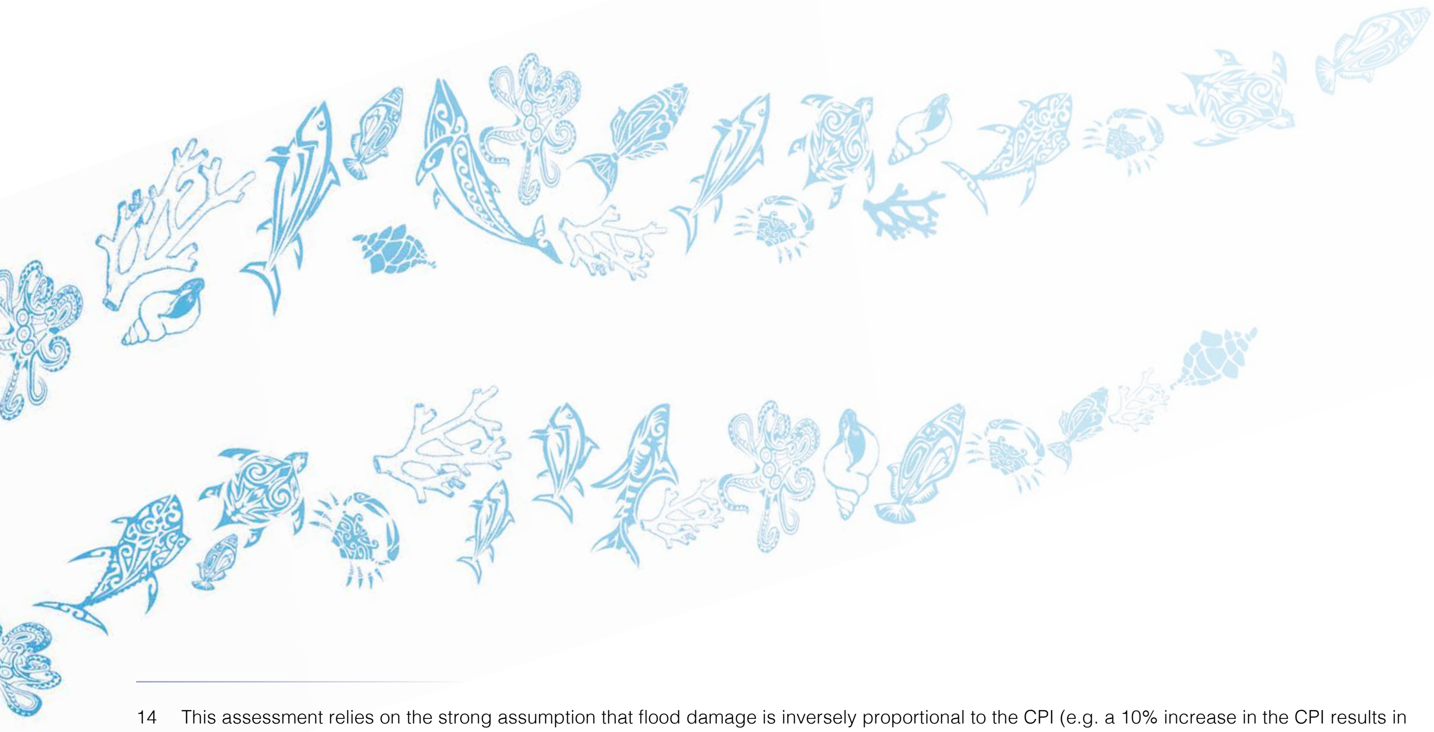
$D_t$ = expected flood damage in year t
$P_t$ = probability of storm surge in year t
CPI = coastal protection index
A = assets at risk (e.g. numbers of houses)
C = construction costs (e.g. cost per house)
DF = damage factor (flood damage as a % of construction cost)

13 An important limitation of this method is that it is only able to assess coastal protection against floods that are caused by extreme climatic events. The role of coral reefs in providing shoreline stabilization and protection against tsunamis is therefore not captured by this method. For example, in the case of Kiribati there are no recorded past extreme climatic events from which to estimate the probability of future events and the value of coastal protection provided by coral reefs in Kiribati could not be estimated (Rouatu et al., 2015).

7. *Compute the avoided damage due to the presence of coral reefs.* Re-calculate the expected damage costs of flooding assuming the absence of coral reef (i.e. set the coastal protection scores for the two factors describing coral reefs in the CPI to the lowest level). The difference between the expected damage with and without reefs is the avoided damage due to the presence of reefs.[14]

Table 5. Characteristics of the coastline included in the coastal protection index (CPI)

| | **Very strong** | **Strong** | **Medium** | **Low** | **None** |
|---|---|---|---|---|---|
| | **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 > 100m) | Coral formation discontin-uous | No reef |
| **Inner slope, crest width** | Very favorable conditions (gentle slope, large crest width) | Favorable conditions (slope, large crest width) | Favorable conditions (at least one condition: slope, crest width) | Reduced favorable 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 |



14 This assessment relies on the strong assumption that flood damage is inversely proportional to the CPI (e.g. a 10% increase in the CPI results in a 10% reduction in damage). The CPI is, however, a qualitative assessment of coastal protection and there is no empirically derived relationship between the CPI and the extent of flood damage.

## BOX 6 COASTAL PROTECTION WORKED EXAMPLE: VANUATU

### Step 1: Identify areas at risk

The three most inhabited islands in Vanuatu are 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 coastal 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 coastal segments. The maximum wave height for Vanuatu is 5 m, derived from the historic maximum height of non-tsunami waves during the last 25 years in tropical regions.

### Step 2: Assess the level of coastal protection for each segment of coast using the coastal protection index

The scores assessed for each coastline factor for each coastal segment are summarised below. The sum of factor scores for each coastal segment is divided by 35 to obtain the standardised CPI value. For the west coast of Efate the calculation is:

$$CPI = 20 / 35 = 0.57$$

Coastal protection scores for Vanuatu (Source: Table 17, Pascal et al., 2015)

| Factor | West coast Efate | East coast Efate | Malekula | Espiritu Santo |
|---|---|---|---|---|
| Geomorphology | 2 | 2 | 2 | 2 |
| Coastal exposure | 4 | 1 | 2 | 3 |
| Reef morphology | 3 | 3 | 3 | 2 |
| Inner slope, crest width | 3 | 3 | 3 | 3 |
| Platform slope | 4 | 4 | 4 | 4 |
| Main depth | 1 | 1 | 1 | 1 |
| Other ecosystems | 3 | 3 | 3 | 3 |
| Sum of factor scores | 20 | 17 | 18 | 18 |
| CPI | 0.57 | 0.49 | 0.51 | 0.51 |

### Step 3: Identify assets at risk

The study assessed the number and location of residential buildings and hotels at risk from coastal flooding. Robust information on other construction works, such as public buildings and infrastructure (e.g. roads, bridges and airports) was not available. Because there was no intensive crop production in the areas at risk, agricultural crops were also not included. In this worked example we focus only on houses to simplify the explanation.

Houses at risk from coastal flooding

| | West coast Efate | East coast Efate | Malekula | Espiritu Santo |
|---|---|---|---|---|
| Assets at risk (houses) | 1,584 | 185 | 203 | 659 |

### Step 4: Estimate damage costs in the event of a flood

The average construction cost of a house in Vanuatu is estimated to be US$ 18,818 and the damage cost to a house, if a flood occurs, is assumed to be a fixed 65% of construction costs (US$ 12,232).

### Step 5: Estimate the probability of a storm surge

The catalogue of historical storms was assembled from the NOAA Historical Hurricane Tracks database. The annual probability of an extreme climatic event is estimated to be 0.42.

## Step 6: Compute the expected annual value of damage due to coastal flooding

Using equation 8 and the parameter values collected in steps 1–5, the expected annual value of damage to houses due to coastal flood can be calculated as illustrated below. For the west coast of Efate the calculation is:

Expected flood damage = 0.42 x (1 - 0.57) x (1,584 x 18,818 x 0.65) = 3,487,494

Expected value of flood damage to houses (US$)

| | West coast Efate | East coast Efate | Malekula | Espiritu Santo |
|---|---|---|---|---|
| Pt = probability of storm surge in year t | 0.42 | 0.42 | 0.42 | 0.42 |
| CPI = coastal protection index | 0.57 | 0.49 | 0.51 | 0.51 |
| A = assets at risk (houses) | 1,584 | 185 | 203 | 659 |
| C = construction costs (house) | 18,818 | 18,818 | 18,818 | 18,818 |
| DF = damage factor (% of construction cost) | 0.65 | 0.65 | 0.65 | 0.65 |
| Dt = expected flood damage in year t (houses) | 3,487,494 | 488,778 | 506,538 | 1,644,377 |

## Step 7: Compute the avoided damage due to the presence of coral reefs

Setting the reef morphology and inner slope values in the CPI to 1 and re-computing the expected value of flooding damage represents the situation without coral reefs. The avoided damage due the presence of coral reefs is computed as the difference between expected flood damage without and with coral reefs. The calculation for the west coast of Efate is:

Avoided damage costs due to coral reefs = 4,417,492 - 3,487,494 = 929,998

Annual avoided damage cost due to the presence of coral reefs (US$/year)

| | West coast Efate | East coast Efate | Malekula | Espiritu Santo |
|---|---|---|---|---|
| Expected flood damage with coral reefs | 3,487,494 | 488,778 | 506,538 | 1,644,377 |
| Expected flood damage without coral reefs | 4,417,492 | 597,395 | 625,723 | 1,934,561 |
| Avoided damage attributable to coral reef | 929,998 | 108,617 | 119,185 | 290,184 |

Source: Pascal et al. (2015)

## 5.5 CARBON SEQUESTRATION

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| Mangroves, other wetlands, seagrass, open ocean | Sequestration of atmospheric carbon and storage in soil and plant matter | Reduced or prevented atmospheric carbon and associated climate change |

Mangroves, wetlands, seagrasses, and even algae (pelagic or benthic) all remove carbon dioxide from the atmosphere and store it in their fibres, in the soil, and/or in the ocean substrate. The amount of carbon that is captured from the atmosphere by different plant species can be quantified in terms of a rate of sequestration. If a tree or plant is destroyed or damaged, the carbon stored in the plant's cells is released as the biomass decays or burns. Carbon stored in the soil/substrate may be released over time if left un-vegetated, or released quickly if the substrate is disturbed. Both the rate at which carbon is added to biomass/substrate (*sequestration rate*) and any release of stored carbon are important. They can be used together to calculate the net change in atmospheric carbon dioxide, in a given time period. The net amount of carbon sequestered by an ecosystem is the sum of the rate of sequestration of each species (*rs,t*) and the amount of stored carbon that would be released if the ecosystem were damaged or destroyed (*qs,t*), per a given time period.

$$\text{Carbon Sequestration}_t = \sum (r_{s,t} + q_{s,t})$$

Equation 9

The subscript *s* refers to the species; the subscript *t* refers to the length of time analysed, usually one year. Data on the rates of carbon sequestration by different ecosystems and the extent of those ecosystems can be used to estimate annual quantities of carbon sequestration; data on the quantity of stored carbon in different ecosystems and reductions in extent of those ecosystems can be used to estimate the annual quantity of carbon prevented from release or decay into the atmosphere.

If an ecosystem is protected, and we assume that the stock biomass and substrate is not being destroyed or damaged, the annual value of carbon sequestration can be estimated by multiplying the annual rate of sequestration by the value per tonne of carbon, as represented by equation 10. This value of a tonne of carbon is a global avoided-costs value, the avoided costs of climate change.

$$\text{Value Carbon Sequestration}_t = \sum (r_{s,t} + q_{s,t}) \bullet \text{Value per tonne carbon}$$

Equation 10

If the carbon stock in biomass and substrate is not disturbed, q = 0. By convention, quantities of carbon are often expressed in terms of tonnes of $CO_2$-equivalent to allow comparison with other greenhouse gases. The conversion rate between carbon and $CO_2$ is 1 t C = 3.67 t $CO_2$. The relevant value per tonne of $CO_2$ is the social cost of carbon (SCC), which is the monetary value of damages caused by emitting one more tonne of $CO_2$ in a given year (Pearce, 2003). The SCC therefore also represents the value of damages avoided for a small reduction in emissions, in other words, the benefit of a $CO_2$ reduction (US EPA, 2014). The SCC is intended to be a comprehensive estimate of climate-change damages but due to current limitations in the integrated assessment models and data used to estimate SCC, it does not include all important damages and is likely to under-estimate the full damages from $CO_2$ emissions. The estimated SCC used by the US EPA and other US agencies for appraisal of emissions reductions in 2015 is US$ 61/tonne $CO_2$, using an annual discount rate of 2.5%.

The observed price in a carbon market is an alternative value per tonne $CO_2$ commonly used in the appraisal of emissions reductions. The problem with this approach is that prices in carbon markets are largely artefacts of the set up and regulation of the market and do not reflect the benefits of carbon sequestration. It is therefore advisable to use SCC for assessments of the global value of carbon sequestration by ecosystems. The use of carbon market prices should, however, be used in financial assessments of carbon sequestration projects in order to reflect potential revenues for the project. An indicative estimate of the price of carbon credits on the voluntary market is provided by Forest Trends (2014), which reports an average price in 2013 of US$ 4.90 t $CO_2$-eq. Carbon market prices reflect value to the resource owners; social costs of carbon represent global avoided-costs values.

Steps in carbon sequestration quantification and valuation:

1. Estimate the quantity of carbon added to the stock of carbon stored in existing coastal ecosystems per year.
   1.1 Obtain data on the current spatial extent of mangroves and seagrass beds.
   1.2 Compute the quantity of carbon sequestered by existing mangroves and seagrasses per year (i.e. the addition to the stored stock of carbon in that single year). Multiply the area of each ecosystem by estimates of the annual sequestration rate of each ecosystem. Where available, use estimates that reflect local species and conditions. The Blue Carbon Initiative of the Nicholas Institute for Environmental Policy Solutions at Duke University has summarised global coastal carbon data and report an average sequestration rate for mangroves of 6.3 t$CO_2$/ha/yr (Murray et al., 2011).[15]
2. Estimate the (potentially avoided) quantity of carbon released due to reductions in area of coastal ecosystems.
   2.1 Identify current rates of change in areas of coastal ecosystems.
   2.2 Compute the change in area of each ecosystem in the current year (total area of ecosystem multiplied by percentage change). The average for Oceania is 0.39% for loss of mangroves (Sifleet et al., 2011); the global average is 0.7–2.1% (Murray et al., 2011).
   2.3 Compute the quantity of stored carbon released to the atmosphere. Here it is necessary to make an assumption regarding the rate at which stored carbon is released following a change in land use from coastal ecosystem to some other land use, such as agriculture or commercial/industrial development.
      2.3.1 Compute the quantity of carbon stored in living biomass using available estimates. For mangroves, average biomass carbon ranges 237–563 t $CO_2$-eq/ha (Murray et al., 2011). Regarding the rate at which biomass carbon is released, it can be assumed that if the mangrove is burned, 75% of biomass carbon of mangroves is released immediately and that the remaining 25% decays with a half-life of 15 years (i.e. a further 12.5% is released within 15 years, a further 6.25% is released within 15 years after that, etc.; Murray et al., 2011).
      2.3.2 Compute the total quantity of carbon stored in soil that is released following removal of the ecosystem using available estimates. The average amount of carbon stored in the top meter of soil beneath mangroves is 1060 t $CO_2$-eq/ha for estuarine mangroves and approximately 1800 t $CO_2$-eq/ha for oceanic mangroves (Murray et al., 2011). Regarding the rate at which this is released, it can be assumed that mangrove soil organic carbon has a half-life of 7.5 years (i.e. 50% of the stored carbon is released in the first 7.5 years, 25% in the following 7.5 years, etc.; Murray et al., 2011).[16]
      2.3.3 Compute the foregone sequestration benefits over time. Sequestration benefits would continue in perpetuity if the ecosystem is not degraded, but because future benefits are typically discounted, a finite time span should be assumed. (Using a 5% discount rate, future annual benefits fall below 50% of current year benefits in about 15 years.)
3. Value the flow of carbon
   3.1 For additions to the stocks of carbon stored in each ecosystem, multiply the annual quantity of sequestered carbon in step 1.2 (t $CO_2$-eq) by the social cost of carbon.
   3.2 For the market value of (potentially avoided) carbon release, the “benefit” is the sale of carbon credits that represent avoided emissions. In this case, multiply the total quantity of (potentially avoided) carbon emissions (t $CO_2$-eq) estimated in step 2.31 and 2.32 by the market price.[17] If relevant cost data is available, subtract the costs of managing and crediting emissions reductions to estimate producer surplus.

---

15 It is advisable to convert all quantities of carbon to tonnes $CO_2$-equivalent (1 t C = 3.67 t $CO_2$-eq) since prices and damage costs of greenhouse gas emissions are most often stated in US$/t $CO_2$-eq. Keeping all quantities in $CO_2$-eq reduces the chance of mixing up the units in which carbon is measured.

16 An alternative assumption, also from Murray et al. (2011), is that oceanic mangroves release 82 t $CO_2$-eq/ha/yr and estuarine mangroves release 59 t $CO_2$-eq/ha/yr for 25 years following clearance of the mangrove trees.

17 This calculation is made with the assumption that avoided emissions that will occur in the future (i.e. as biomass and soil carbon is released over time) can be credited and sold in the current year. If this is not the case, it would be necessary to estimate the quantity of carbon released in each year following the land use change and then compute a present value of the stream of credits.

## **BOX 7** CARBON SEQUESTRATION WORKED EXAMPLE 1: KIRIBATI

The area of mangrove in Kiribati is 790 ha. Any current change in the area of mangrove is negligible and so the valuation focuses on the value of carbon that is added to the quantity stored in biomass and soil. The additional quantity of stored carbon is computed as the area of mangrove multiplied by the annual rate of carbon sequestration per unit area. This quantity is then multiplied by the value of carbon (social cost of carbon). The parameter values are given below and the calculation for Kiribati is:

Annual value of carbon sequestration = 790ha x 6.3 t $CO_2$/ha/year x $61 = US$303,597

Value of carbon sequestration by mangroves

| | Units | Values | Source |
|---|---|---|---|
| Mangrove area | Hectares (ha) | 790 | Lands Division (MELAD) |
| Carbon sequestration rate | t $CO_2$/ha/year | 6.3 | Murray et al. (2011) |
| Carbon sequestered per year | t $CO_2$/year | 4,977 | |
| Social cost of carbon | USD/t $CO_2$ | 61 | US EPA (2014) |
| Annual avoided-costs value of Carbon sequestration | US$ | 303,597 | |

Source: Rouatu et al. (2015)

## BOX 8 CARBON SEQUESTRATION WORKED EXAMPLE 2: SOLOMON ISLANDS

This worked example illustrates the steps in calculating the potential market value of avoiding the release of carbon from mangroves at risk for destruction in the Solomon Islands.

### Step 1. Estimate the quantity of carbon added to the stock of carbon stored in mangroves

#### Step 1.1 Obtain data on the current spatial extent of mangroves

The total area of mangroves in the Solomon Islands is 56,100 hectares.

#### Step 1.2 Compute the quantity of carbon sequestered per year

The average carbon sequestration rate for mangroves is 6.3 t $CO_2$/ha/yr.

### Step 2. Estimate the quantity of carbon released due to reductions in area of coastal ecosystems

#### Step 2.1 Identify current rates of change in areas of coastal ecosystems

The current rate of loss of mangrove area is 1.7% per year.

#### Step 2.2 Compute the change in area of each ecosystem in the current year

The loss of mangrove area per year = 56,100ha x -0.017/yr = -954ha/yr

#### Step 2.3 Compute the quantity of stored carbon released to the atmosphere

##### Step 2.3.1 Compute the quantity of carbon in living biomass that is released into the atmosphere following mangrove loss.

Mangrove biomass carbon is 237 t $CO_2$/ha and the rate at which it is released is assumed to be 75% immediately and that the remaining 25% decays with a half-life of 15 yr. So the quantity of biomass carbon released to the atmosphere during 15 yr following mangrove loss is computed as:

Biomass carbon released per hectare =

(237 t $CO_2$/ha x 0.75) + ((237 t $CO_2$/ha x 0.25) / 2) = 207 t $CO_2$/ha

##### Step 2.3.2 Compute the quantity of carbon stored in soil released following mangrove loss.

The average amount of carbon stored in the top meter of soil beneath mangroves is 1,690 t $CO_2$-eq /ha. The rate at which this is released is assumed to have a half-life of 7.5 yr. So the quantity of soil carbon released to the atmosphere during 15 yr following mangrove loss is computed as:

Soil carbon released per hectare =

(1,690 t $CO_2$/ha x 0.5) + (845 t $CO_2$/ha x 0.5) = 1,268 t $CO_2$/ha

##### Step 2.3.3 Compute the foregone carbon sequestration for a selected time frame.

Over the next 15 years, foregone sequestration from 1 ha lost is calculated as:

Foregone sequestration = 15yr x 6.3 t $CO_2$/ha/yr = 94.5 t $CO_2$/ha

The total additional, or potentially avoided, $CO_2$ in the atmosphere (after 15 yr) resulting from 1 ha of mangrove loss is the sum of foregone sequestration and released carbon from biomass and soil:

Potentially avoided t $CO_2$-eq /ha per hectare = 94.5 + 207 + 1,268 = 1,569 t $CO_2$/ha

The total potentially avoided $CO_2$ in the atmosphere is computed by multiplying the quantity of emissions per hectare by the area of predicted loss per year:

Potentially avoided t $CO_2$ = 1,569 t $CO_2$/ha x 954 ha/yr = 1,496,713 t $CO_2$/yr

## Step 3. Value the flow of carbon

### Step 3.2. Estimate the market value of potentially avoided carbon in the atmosphere.

The market value of potentially avoided carbon emissions is estimated as the total quantity of carbon released multiplied by the market price. The observed market price for one t $CO_2$ of avoided emissions is US$ 4.90. The market value of preventing mangrove loss in one year is computed as:

$$\text{Market value of carbon (US\$)} = 1{,}496{,}713 \text{ t } CO_2/\text{yr} \times \$4.9 = \text{US\$}7{,}333{,}893$$

Potential market value of carbon sequestration by mangroves in Solomon Islands

| | Units | Values | Source |
|---|---|---|---|
| Mangrove area | ha | 56,100 | |
| Annual rate of loss | % | 1.7 | |
| Annual area loss | ha | 954 | |
| Carbon seq. rate | t $CO_2$/ha/yr | 6.3 | Murray et al. (2011) |
| Mangrove biomass carbon | t $CO_2$/ha | 237 | Murray et al. (2011) |
| Soil biomass carbon | t $CO_2$/ha | 1,690 | Murray et al. (2011) |
| Biomass carbon initial release | % | 75 | Murray et al. (2011) |
| Biomass carbon half-life | yr | 15 | Murray et al. (2011) |
| Soil carbon (top 1 m) half-life | years | 7.5 | Murray et al. (2011) |
| Carbon release from biomass (15 yr) | t $CO_2$/ha | 207 | |
| Carbon release from soil (15 yr) | t $CO_2$/ha | 1,268 | |
| Foregone sequestration (15 yr) | t $CO_2$/ha | 95 | |
| Carbon emissions (15 yr total) | t $CO_2$/ha | 1,563 | |
| Annual carbon release | t $CO_2$ | 1,496,713 | |
| Market price of carbon | US$/t $CO_2$ | 4.90 | Forest Trends (2014) |
| Market value of protecting mangroves, per year | US$ | 7,333,893 | |

Source: Arena et al. (2015)

## 5.6 RESEARCH, EDUCATION AND MANAGEMENT

| Ecosystems | Ecosystem functions | Ecosystem service |
|---|---|---|
| All plants and animals, including microscopic organisms and bio-chemical processes | Biodiversity (existence) | Facilitation of education, research, and management |

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

The boundaries of our analysis are at the country level. As a result, domestic governmental expenditures on biodiversity are not counted towards economic value, as internal transfers are a redistribution of resources, not new economic value. However, international governmental and NGO expenditures on aid and grants, including for research, training and education, are appropriately counted as an economic benefit. Much as income from tourism is payment for an exported service, this is 'new money' within the recipient country. For example, the Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project is funded by German tax revenue. For the countries in which the MACBIO project is implemented (Fiji, Solomon Islands, Kiribati, Vanuatu and Tonga), this redistribution is an investment and should be counted as an economic benefit. When foreign (or domestic) investments result in remittances or transfers of financial resources out of the country, the economic development (multiplier) effect of those investments will be lower due to this 'leakage'. Similarly, the distributional effect of these investments throughout the economy may be influenced by whether local or international labour and capital are engaged.

### BOX 9 RESEARCH, EDUCATION AND MANAGEMENT WORKED EXAMPLE: SOLOMON ISLANDS

Foreign funded projects managed by the Solomon Islands Ministry of Fisheries and Marine Resources were worth US$ 1.2 million in 2013. Given the nature of the projects, it is likely that they are mostly focused on management of marine and coastal resources, with some minor contributions to education and research. It should be noted that the costs of acquiring, managing and implementing these projects has not been estimated and subtracted from the funds received.

Foreign funded projects of the Ministry of Fisheries and Marine Resources

| Project | Project funding (US$) |
|---|---|
| Tuna loin factories project, Suva Bay and Tenaru | 586,957 |
| Wantok project, Doma | 130,435 |
| Fish aggregation device program | 130,435 |
| Provincial fisheries housing project | 130,435 |
| Rehabilitation of Fisheries Centre | 221,739 |
| Total | 1,200,000 |

Source: Arena et al. (2015)

# 6 CONCLUDING REMARKS

The methods described in this guidance manual offer resource managers a simple approach to estimating the monetary value of human benefits from ecosystems. Monetary measures can serve to highlight the real, tangible benefits of healthy ecosystems and allow resource managers to compare ecosystem services to other goods, services, and policy measures. However, it is important that monetary measures of ecosystem benefits be accompanied by a clear explanation of what has been measured.

The methods presented in this manual calculate a snapshot of ecosystem service value for a given year or average of years. Ecosystems function dynamically and the provision of ecosystem services can vary from year to year, decade to decade. In particular, populations of species increase and decrease according to climate, seasons, and human pressures. An annualized value of an ecosystem service does not tell resource managers much about this dynamic process. Annualized values typically represent a flow of benefits, and do not describe the value of the *stock* of natural capital that supports these annual benefits or indicate sustainable resource use. These limitations should be explained when presenting snapshot, annual measures of ecosystem service value.

Managing natural capital to generate the greatest human benefits requires an understanding of long-run sustainability on the scale of tens or even hundreds of years. Providing information to resource managers to achieve this involves modelling dynamic ecosystem processes, changes to natural capital stocks and the implications for ecosystem services. This is a more complex level of analysis than can be communicated in a guidance manual and goes beyond what can reasonably be expected of resource managers.

The information that is produced by the methods described in this manual is useful in resource management and can aid practical decision-making about marine and coastal ecosystem services. Although information on annual values is focused on the short term, it is directly applicable to many decision contexts; many business activities, development projects, and political decisions are made on an annual or, at most, decadal calendar, and so annualized values allow for convenient comparison. Annualized values are useful to highlight the fact that ecosystems have real economic value, provide tangible, quantifiable benefits to humans, and therefore should be managed and protected in ways that can maximize human welfare today, and for generations to come.

# 7 BIBLIOGRAPHY


Arena M., Wini L., Salcone J., Pascal N., Fernandes L., Brander L., and Wendt H. (2015) Economic assessment and valuation of marine ecosystem services: Solomon Islands. MACBIO GIZ/IUCN/SPREP, Suva, Fiji. 110 pp.

Boardman, A.E., Greenberg, D.H., Vining, A.R., and Weimer, D.L. (2006) *Cost-Benefit Analysis: Concepts and Practice. Pearson Education, New Jersey,* 3rd Edition.

Boyd, J., and Banzhaf, S. (2007) What are ecosystem services? The need for standardised environmental accounting units. *Ecological Economics* 63, 616–626. Online*:* https://www.flseagrant.org/wp-content/uploads/2012/01/Boyd_What.pdf

Brander, L. (2013) Guidance manual on value transfer methods for ecosystem services. United Nations Environment Programme, Nairobi, Kenya.

Burke, L., Greenhalgh, S., Prager, D., and Cooper, E. (2008). Coastal capital: economic valuation of coral reefs in Tobago and St. Lucia. World Resources Institute, Washington, USA

Caesar, H. (1996). *Economic Analysis of Indonesian Coral Reefs. World Bank Environment Department. Online:* http://siteresources.worldbank.org/INTEEI/214574-1153316226850/20486385/EconomicAnalysisofIndonesianCoralReefs1996.pdf

Chan, K.M., Satterfield, T., and Goldstein, J. (2012) Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics 74, 8–18.

Das, S., and Vincent, J.R. (2009) Mangroves protected villages and reduced death toll during Indian super cyclone. Proceedings of the National Academy of Sciences USA 106, 7357–7360

Daubert, J.T., and Young, R.A. (1981) Recreational demands for maintaining instream flows: a contingent valuation approach, *Journal of Agricultural Economics* 63, 666–676 Online*:* www.jstor.org/stable/1241209

Environmental Protection Agency, *Guidelines for Preparing Economic Analyses* xv (Dec 17, 2010)

Fiji Fisheries Department (2014) Department of Fisheries Annual Report 2013. Ministry of Agriculture Forests and Fisheries, Suva.

Fisher, B., Turner, K.R. and Morling, P. (2009) Defining and classifying ecosystem services for decision making. *Ecological Economics* 68, 643–653. Online: http://www.uvm.edu/giee/pubpdfs/Fisher_2009_Ecological_Economics.pdf

Forest Trends (2014) Sharing the stage: State of the voluntary carbon markets 2014. Available at www.forest-trends.org/documents/files/doc_4841.pdf

Gillett, R. (2009) The contribution of fisheries to the economies of Pacific island countries and territories. Pacific Studies Series, Asian Development Bank, Manila, The Philippines

Gonzalez, R., Ram-Bidesi, V., Pascal, N., Brander, L., Fernandes, L., Salcone, J., and Seidl, A. (2015) Economic assessment and valuation of marine ecosystem services: Fiji. A report to the MACBIO project. GIZ/IUCN/SPREP, Suva. 120 pp.

Greer Consulting Services (2007) Economic analysis of aggregates mining on Tarawa Project Report 71b, EU EDF 8 – SOPAC (Pacific Islands Applied GeoScience Commission) 52 pp.

Jungwiwattanaporn, M., and Pendleton, L. (2014) Economic values for Pacific Island ecosystems: a compilation of values from the Marine Ecosystem Services Partnership (MESP). Nicholas Institute for Environmental Policy Solutions, Duke University.

Kench, P.S., and Brander, R.W. (2006) Wave processes on coral reef flats: implications for reef geomorphology using Australian case studies. Journal of Coastal Research 2006, 209–223.

Loomis, J.B., Kent, P., Strange, L., Fausch, K. and Covich, A. (2000) Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation study. Ecological Economics 33, 103–117.

MA (Millennium Ecosystem Assessment) (2005) Global Assessment Reports. Island Press: Washington DC. http://www.millenniumassessment.org/ (Accessed 13/3/17)

McKenzie, E., Woodruff, A., and McClennen, C. (2006) Economic assessment of the true costs of aggregate mining in Majuro atoll Republic of the Marshall Islands. South Pacific Applied Geoscience Commission (SOPAC), Suva.

Murray B, Pendleton L, Jenkins AW, Sifleet S (2011) Green payments for blue carbon: economic incentives for protecting threatened coastal habitats. Nicholas Institute Report NI R 11-04. Nicholas Institute, Washington DC.

O'Garra T (2007) Estimating the Total Economic Value (TEV) of the Navakavu LMMA (Locally Managed Marine Area) in Vitu Levu island (Fiji). Final report for Coral Reef Initiatives for the Pacific, Noumea, New Caledonia.

Pascal, N. (2010) Écosystèmes coralliens de Nouvelle-Caledonie. Valeur économique des services écosystèmiques. Partie I: Valeur financiè*re.* IFRECOR Nouvelle-Caledonie, Noumea.

Pascal, N. (2013). *Economic Valuation of Mangrove Ecosystem Services in Vanuatu.* IUCN MESCAL. Online: http://www.ircp.pf/wp-content/uploads/20130913_MESCALeconomic-valuation-of-mangrove-ecosystems-in-vanuatu.pdf

Pascal, N., (2013). Analysis of economic benefits of mangrove ecosystems. Case studies in Vanuatu: Eratap and Crab Bay. IUCN ORO International Union for Conservation of Nature and Natural Resources, Oceania Regional Office. Project MESCAL, Mangrove EcoSystems for Climate Change Adaptation & Livelihoods. Technical report, 147 pages.

Pascal, N., Molisa, V., Wendt, H., Brander, L., Fernandes, L., Salcone, J., and Seidl, A. (2015) Economic assessment and valuation of marine ecosystem services: Vanuatu. A report to the MACBIO project. GIZ/IUCN/SPREP, Suva, Fiji, 103 pp.

PCRAFI, (2011a). Pacific Catastrophe Risk Assessment and Financing Initiative, country risk profile: Fiji. World Bank, Asian Development Bank and SPC/SOPAC. Technical report - Risk assessment methodology: 18 pp.

PCRAFI, (2011b). Pacific Catastrophe Risk Assessment and Financing Initiative, country risk profile: Fiji. World Bank, Asian Development Bank and SPC/SOPAC. Technical report.

Pearce, D. (2003) The social cost of carbon. Oxford Review of Economic Policy 19, 362–384.

Rittenberg, L. and Tregarthen, T. (2009) Principles of Microeconomics, v. 1.0. Flat World Knowledge, Washington, D.C.. http://ocw.mit.edu/ans7870/14/14.01SC/MIT14_01SCF11_rttext.pdf

Rouatu, I., Leport, G., Pascal, N., Wendt, H., and Abeta, R. (2015) Economic valuation of marine ecosystem services of Kiribati. A report to the MACBIO project. GIZ/IUCN/SPREP, Suva, Fiji, 102 pp.

Salcone, J., Tupou-Taufa, S., Brander, L., Fernandes, L., Fonua, E., Matoto, L., Pascal, N., Seidl, A., Tu'ivai, L., and Wendt, H. (2015) Economic assessment and valuation of marine ecosystem services: Tonga. A report to the MACBIO project. GIZ/IUCN/SPREP, Suva, Fiji. 135 pp.

Sifleet S, Pendleton L, Murray BC (2011) State of the science on coastal blue carbon: a summary for policy makers. Nicholas Institute Report 11-06, Nicholas Institute, Washington DC.

SPC (2013) Deep-sea minerals: deep-sea minerals and the green economy. Baker, E., and Beaudoin, Y. (Eds.) Vol. 2, Secretariat of the Pacific Community, Noumea, New Caledonia.

Stern, N. (2007). The economics of climate change: the Stern Review. Cambridge University Press, Cambridge, UK.

TEEB (The Economics of Ecosystems and Biodiversity) (2013) Guidance manual for TEEB country studies. Version 1.0. The Economics of Ecosstems and Biodiversity, Geneva, Switzerland. Online: http://www.teebweb.org/resources/guidance-manual-for-teeb-country-studies/

US EPA (2014) The social cost of carbon. http://www.epa.gov/climatechange/EPAactivities/economics /scc.html Accessed on 20 August 2014.

Van Beukering P, Haider W, Longland M, Cesar H, Sablan J, Shjegstad S, Beardmore B, Liu Y, Garces GO (2007b) The economic value of Guam's coral reefs. Marine Laboratory Technical Report No. 116. University of Guam.

van Beukering, P., Brander, L., Tompkins, E., McKenzie, E. (2007). Valuing the environment in small islands: an environmental economics toolkit. Joint Nature Conservation Committee, United Kingdom. Online:

World Bank (2012) Gross National Income online: http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD

# ANNEX I
# OTHER GUIDELINES AND MANUALS

There are a number of useful publications and manuals that provide guidance on economic valuation of ecosystem services. A selection of these resources is listed below according to the topic that they address.

## PRIMARY VALUATION


Pearce, D., and Özdemiroglu, E. (2002) Economic valuation with stated preference techniques summary guide (2002) Department of Transport, Local Government and Regions, London

Freeman, A.M.I. (2003) The measurement of environmental and resource values. Resources for the Future, Washington D.C.

Barbier, E., Acreman, M., and Knowler, D. (1997) Economic valuation of wetlands: a guide for policy makers and planners. Ramsar Convention Bureau, Gland, Switzerland http://www.ramsar.org/pdf/lib/lib_valuation_e.pdf

Brouwer, R., Barton, D.N., Bateman, I.J., Brander, L., Georgiou, S., Martin-Ortega, J., Navrud, S., Pulido-Velazquez, M., Schaafsma, M., and Wagendonk, A. (2009) Economic valuation of environmental and resource costs and benefits in the water framework directive: technical guidelines for practitioners (2009). Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, NL, 240pp

OECD (2002) Handbook on biodiversity valuation. Organisation for Economic Cooperation and Development, Paris http://earthmind.net/rivers/docs/oecd-handbook-biodiversity-valuation.pdf

Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services. https://www.gov.uk/ecosystems-services

UNEP (2014) Guidance manual on valuation and accounting of ecosystem services for Small Island Developing States. Ecosystem Services Economics Unit, Division of Environmental Policy Implementation, United Nations Environment Program, Nairobi, Kenya

DEFRA (2007) An introductory guide to valuing ecosystem services. Department for Environment, Food and Rural Affairs, UK https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69192/pb12852-eco-valuing-071205.pdf

Swedish EPA (2006) An instrument for assessing the quality of environmental valuation studies. Swedish Environmental Protection Agency, Stockholm, Sweden http://www.naturvardsverket.se/Documents/publikationer/620-1252-5.pdf

Bann, C. (2003) The economic valuation of mangroves: a manual for researchers. Environmental Economics Programme for South East Asia, Singapore http://network.idrc.ca/uploads/user-S/10305674900acf30c.html

Bann, C. (2003) The economic valuation of tropical forest land use options: a manual for researchers Environmental Economics Programme for South East Asia, Singapore http://www.idrc.ca/uploads/user-S/10916232241spcbann1.pdf

Waite, R., Burke, L., Gray, E., van Beukering, P., Brander, L., McKenzie, E., Pendleton, L., Schuhmann, P., and Tompkins, E. (2014) Coastal capital:ecosystem valuation for decision making in the Caribbean. World Resources Institute, Washington, D.C. http://www.wri.org/publication/coastal-capital-guidebook

Hanley, N., and Barbier, E. (2009) Pricing nature: cost-benefit analysis and environmental policy. Edward Elgar Publishing, Cheltenham, UK

Champ, P.A., Boyle, K.J. and Brown, T.C. (eds.) (2003) A primer on nonmarket valuation. Kluwer Academic Publishers, Dordrecht, Netherlands

German Agency for International Cooperation (GIZ) (2016) ValuES: methods for integrating ecosystem services into policy, planning, and practice, GIZ. http://aboutvalues.net/

## VALUE TRANSFER


Brander, L. (2013) Guidance manual on value transfer methods for ecosystem services. United Nations Environment Programme. http://capacity4dev.ec.europa.eu/unep/document/guidance-manual-value-transfer-methods-ecosystem-services

Dumas, C.F., Schuhmann, P.W., and Whitehead J.C. (2005) Measuring the economic benefits of water quality improvement with benefit transfer: an introduction for non-economists. In: Brown, L.R., Gray, R.H., Hughes, R.M, and Meador, M. (eds), Effects of urbanisation on stream ecosystems. American Fisheries Society Symposium 47, American Fisheries Society, Bethesda, MD.

Navrud, S. (2007) Practical tools for value transfer in Denmark – guidelines and an example. Working Report No. 28, Danish Environmental Protection Agency, Copenhagen http://www2.mst.dk/udgiv/publications/2007/978-87-7052-656-2/pdf/978-87-7052-657-9.pdf

Navrud, S., and Ready, R. (2007) Environmental value transfer: issues and methods. Springer, Dordrecht

Economics for the Environment Consultancy (eftec) (2010) Valuing environmental impacts: practical guidelines for the use of value transfer in policy and project appraisal. Department for Environment, Food and Rural Affairs, London https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182376/vt-guidelines.pdf

European Environment Agency (2010) Scaling up ecosystem benefits – a contribution to The Economics of Ecosystems and Biodiversity (TEEB) study. EEA Technical Report 4/2010, Copenhagen

Improving the use of environmental valuation in policy appraisal: a value transfer strategy (2010). Department for Environment, Food and Rural Affairs; Environment Agency; Natural England; and Forestry Commission.

Rosenberger, R.S., and Loomis, J.B. (2001) Benefit transfer of outdoor recreation use values. A technical document supporting the Forest Service Strategic Plan (2000 revision). General Technical Report RMRS-GTR-72. Rocky Mountain Research Station, U.S. Department of Agriculture Forest Service, Fort Collins, CO, 59 pp

# APPENDIX I GLOSSARY

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

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

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

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

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

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

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

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

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

**Demand**: The amount of a good or service consumed or used at a given price; consumers will demand a good or service if the benefit is at least as high as the price they pay.

**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.

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

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

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

**Inflation**: A general rise in prices in an economy.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Social cost of carbon**: The social cost of carbon is an estimate of the economic damages associated with a small increase in carbon dioxide ($CO_2$) emissions, conventionally one tonne, in a given year. This dollar figure also represents the value of damages avoided for a small emission reduction (i.e. the benefit of a $CO_2$ reduction).

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

**Supply**: The quantity of a good or service that producers will supply at a given price; producers will supply goods and services if they at least cover their costs.

**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/Utility**: A measure of human welfare or satisfaction. Synonymous with economic value.

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

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

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

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

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

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

MACBIO

Marine and Coastal Biodiversity Management
in Pacific Island Countries

www.macbio-pacific.info