Guidance on the economic valuation of ecosystem services and natural capital of the Area

Prepared by Dr. Luke Brander[1,2] in response to the call for proposals issued by the International Seabed Authority for a consultancy to undertake a study on the environmental costs of exploitation activities in the Area (Contract No. ISA/2023/OEMMR002).

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[1] Institute for Physical Geography and Landscape Ecology, Leibniz Universität Hannover, Germany.

[2] Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, The Netherlands.

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Background to the development of this guidance report

The International Seabed Authority (ISA) is an international organisation established under the 1982 United Nations Convention on the Law of the Sea and the 1994 Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea. The ISA is the organisation through which States Parties to the Convention shall, in accordance with the regime for the seabed and ocean floor and subsoil thereof beyond the limits of national jurisdiction (the Area) established in Part XI and the Agreement, organize and control activities in the Area, particularly with a view to administering the resources of the Area. The ISA is required to take the measures necessary to ensure effective protection for the marine environment from harmful effects, as set out in the Convention.

In July 2018, the Council of the ISA established an open-ended working group to discuss a financial model and payment mechanism for deep-sea mineral resource exploitation. At its fourth meeting (November 2022), the working group decided to request the Secretary-General of the ISA to commission a study on the environmental costs of exploitation activities, including how to internalize the costs associated with environmental externalities. The outcome of this study does not in any way prejudice the decision of the Council of ISA, to be taken at a later stage, whether the exploitation regulations shall include a mechanism for the internalisation of environmental costs.

The first output of this study identifies the key ecosystem services provided by seabed habitats in the Area, and the second output reviews the existing literature on the economic value of these services. These outputs are published in a separate report on the value of ecosystem services and natural capital of the Area (Brander and Guisado Goñi, 2023). The present report is the third output of this study and provides guidance for conducting valuations of the impacts of resource exploitation on ecosystem services.

Acronyms

CICES	Common International Classification for Ecosystem Services
DSM	Deep-sea Mining
EIA	Environmental Impact Assessment
ES	Ecosystem Services
FEGS	Final Ecosystem Goods and Services
GDP	Gross Domestic Product
GIS	Geographic Information System
IPBES	International Panel of Biodiversity and Ecosystem Services
ISA	International Seabed Authority
MA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
SCC	Social Cost of Carbon
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
WTP	Willingness To Pay

1. Introduction

1.1 What are we seeking to value, why and how?

The natural environment, including seabed habitats in the Area, provides a wide range of goods and services that contribute to the well-being of people. In short, the various benefits that ecosystems provide to people are termed "ecosystem services" and their importance to human well-being is termed "value" (see Figure 1). The values of ecosystem services depend on the quantities that are supplied by ecosystems and demanded by people and will therefore vary greatly across locations with different environmental conditions and populations of beneficiaries. Sections 2 and 3 provide a detailed introduction to ecosystem services and systems for classifying them.

Exploitation of mineral resources in the Area would potentially have negative impacts on marine ecosystems and the services they provide. These unintended consequences of resource exploitation are termed "external costs" since they are not incurred by the mine operator but by other groups in society (the beneficiaries of ecosystem services that face reduced supply). Information on the scale of external costs from mining activities can be used to evaluate the net gain or losses of resource exploitation from a societal perspective and for determining compensation for environmental damage. Note that this guidance document is focussed on the valuation of external costs and does not address the assessment of direct private costs, revenues or other benefits of resource exploitation that would be necessary to estimate societal net benefits. Section 3 expands on the case for valuation of marine ecosystem services.

Quantifying the economic value of external costs requires an understanding of the impact pathway of mining activities on ecosystems, the provision of services, and their contribution to human well-being (conventionally measured in monetary units). This is challenging given the stacked uncertainties and gaps in data and knowledge. Regarding monetary valuation, many ecosystem services are openly accessible and are not traded in markets, for example, climate regulation by phytoplankton and biodiversity provided by seamounts. As such, the value of such services are not readily observable. In response, a wide range of non-market valuation methods have been developed to measure the importance of ecosystem services to human well-being (see Section 5) and to inform the use and management of marine ecosystems. This guidance report sets out the rationale and methods for valuation of ecosystem services to help manage the biotic natural capital of the Area.

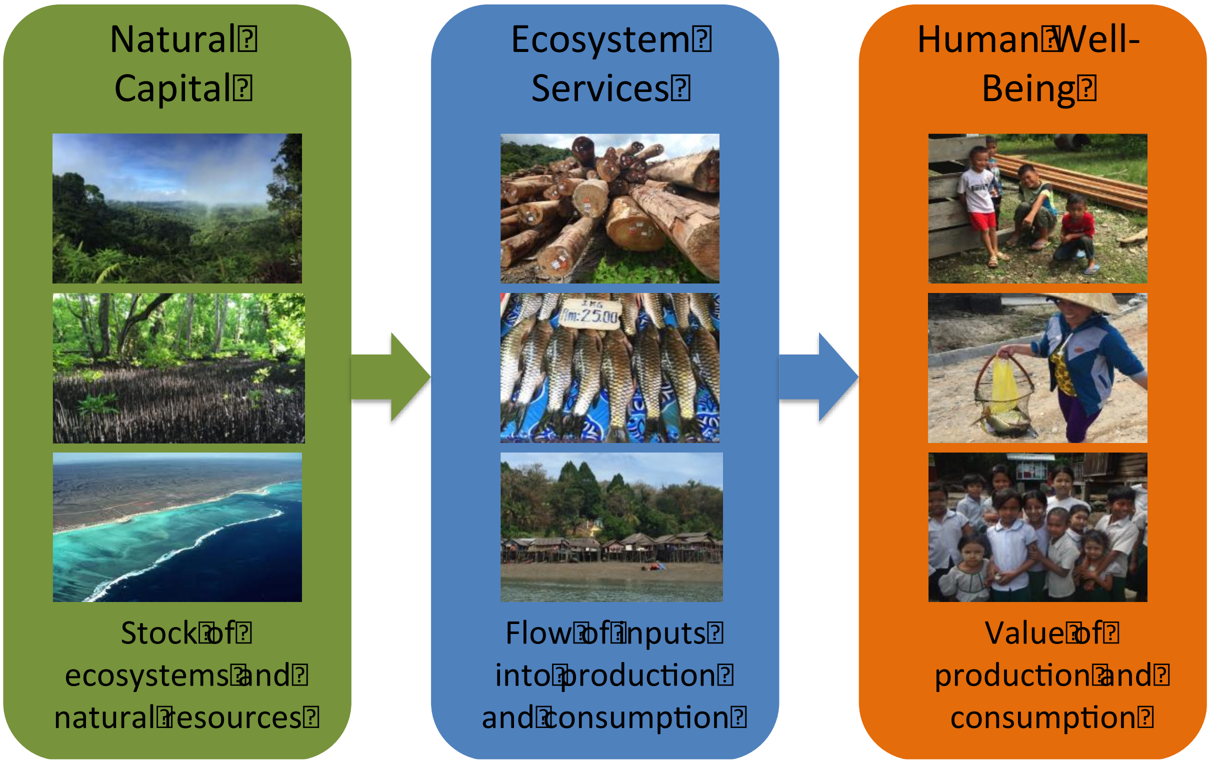

Figure 1. The contribution of natural capital and ecosystem services to human well-being. Source: Brander (2018).

1.2 Who is this guidance report for?

The purpose of this guidance report is to explain how methods for valuing marine ecosystems can be used to produce information to support decision-making in the context of deep-sea mining activities in the Area. Specifically, it is designed to help mining operators to understand the available methods for valuing the impacts of resource exploitation on ecosystem services. This guidance report has been written with the context of the Area in mind and could potentially be further tailored to suit specific regions and deep-sea habitats.

The broad objective of this guidance report is to provide an understanding of how valuation methods can be used to quantify the impact of mineral exploitation on ecosystem services in economic terms. To this end, the report provides:

- An introduction to the main frameworks for identifying values for marine ecosystems;
- Non-technical explanations of valuation methods and their applicability to different ecosystem services;
- An explanation of the strengths and limitations of each valuation method; and
- Links to available resources and manuals for conducting valuation of marine ecosystems.

1.3 How to use this guidance report

The aim is to provide practical guidance on the use of valuation methods in the context of the impacts of resource exploitation in the Area. To be able to use this guidance, a basic understanding and experience of applied environmental economics is useful but not necessary. For users that are unfamiliar with environmental economics or need a refresher, a brief introduction to relevant basic principles is provided in Annex 1.

Each section of the guidance report describes a distinct step in the process of delivering information on the value marine ecosystems. Users can go directly to the sections that are relevant to their needs. Links between steps are highlighted so that users can navigate between sections to suit their purposes. The guidance report provides an introduction to each valuation method, guidance on what information each method can be used to produce, and the strengths and limitations of each. It does not provide step-by-step technical instructions on how to conduct each method since many of the methods require separate dedicated manuals. Throughout the guidance report, references are made to other useful resources. This guidance report can and should be used alongside these other resources.

It should be noted that the production of information on the value of marine ecosystems requires input from multiple fields of expertise. A general description of a decision process that involves impacts on the environment includes the following steps: description of investment activity, identification of impacts (e.g. through an Environmental Impact Assessment), bio-physical assessment, economic valuation, investment evaluation, mitigation and/or compensation. These steps require inputs from many fields of expertise (e.g., mining engineers, marine biologists, ecologists, economists, policy analysts). Although the emphasis of this guidance report is on economic valuation methods, these other crucial elements in the assessment process should not be ignored.

2. Ecosystem Services and Natural Capital

2.1 The ecosystem services framework

The concept of ecosystem services provides a useful framework to identify the importance of the natural environment to humans. The term "ecosystem services" has been defined in a number of different ways (see summary of definitions in Box 1) but put most simply, they are the variety of benefits that humans obtain from the environment.

Ecosystems contribute to human well-being in a variety of ways and the processes by which ecosystems provide benefits to people has been described as an "ecosystem services cascade" in which bio-physical structures and processes ("ecosystem functions") can deliver inputs (ecosystem services) to the production of goods and services that are consumed by people (see Figure 2).

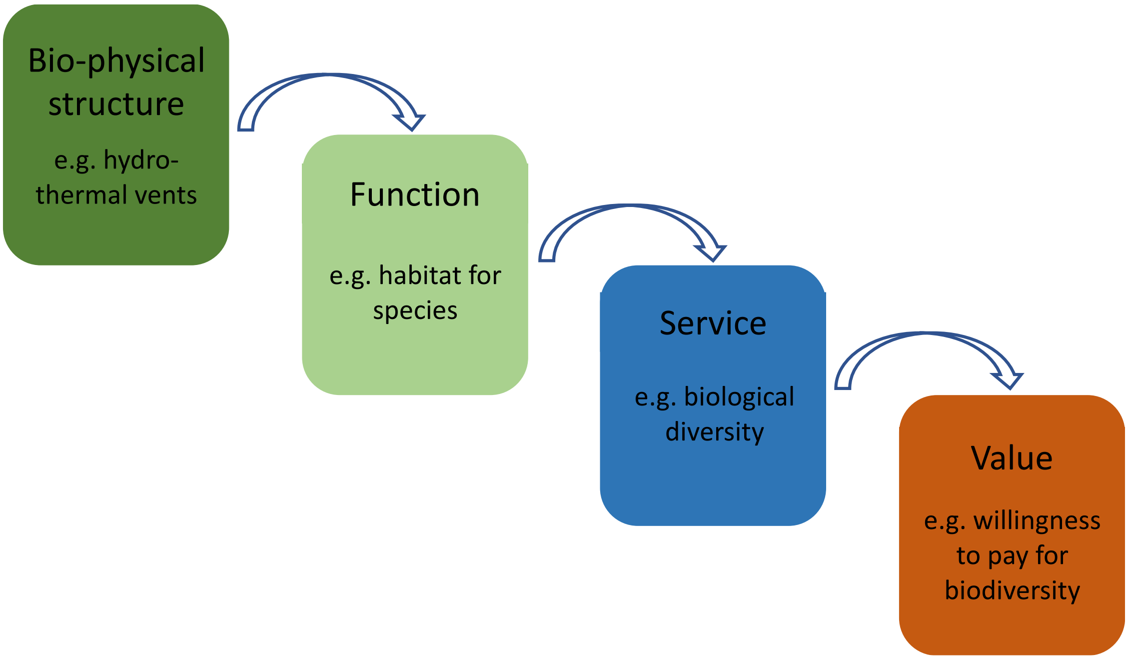

Figure 2. Ecosystem services "cascade". Adapted from Haines-Young and Potschin (2010).

Box 1. Defining ecosystem services

The conceptualization and understanding of ecosystem services has gradually been refined over the past 20+ years and a number of different definitions have been provided by different initiatives. These include:

- Ecosystem services are the benefits that ecosystems provide for people (Millennium Ecosystem Assessment – MA 2005).
- Ecosystem services are the direct and indirect contributions of ecosystems to human well-being (The Economics of Ecosystems and Biodiversity – TEEB; Kumar 2012)
- Ecosystem services refer to those contributions of the natural world that are used to produce goods which people value (UK National Ecosystem Assessment – UKNEA, 2011).

- Ecosystem services are the contributions that ecosystems make to human well-being (Common International Classification of Ecosystem Services – CICES; Haines-Young and Potschin 2012).
- The US Environmental Protection Agency (US EPA) use the term “final ecosystem goods and services” (FEGS) to mean “components of nature, directly enjoyed, consumed or used to yield human well- being” (Landers and Nahlik, 2013).
- The EU Mapping and Assessment of Ecosystems and their Services (MAES) working group defines ecosystem services as “the contributions of ecosystem structure and function (in combination with other inputs) to human well-being” (Burkhard and Maes, 2017)
- The International Panel of Biodiversity and Ecosystem Services (IPBES) introduced an additional term for ecosystem services – “nature’s contributions to people” (NCP) – to describe the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people’s quality of life (Diaz *et al*., 2018).

2.2 Natural capital

Ecosystem services can also be viewed as the flow of benefits received from “ecosystem capital” – see Figure 3. Ecosystem capital is a component of natural capital, which can be defined as the stock of natural assets that provide society with renewable and non-renewable resources and a flow of ecosystem services (Dasgupta, 2021). Natural capital includes abiotic assets (e.g. fossil fuels, minerals, metals) and biotic assets (ecosystems that provide a flow of ecosystem services). The biotic component of natural capital is termed ecosystem capital. Natural capital is analogous to built capital (e.g. transport infrastructure), human capital (e.g. a skilled and educated work force) or social capital (e.g. rules, norms and trust) as an input to the production of goods and services that humans consume. Natural capital may be both a complement to other forms of capital (i.e. used in combination with them to produce goods and services) or a substitute (used instead of other forms of capital). In the present study, the focus is on the ecosystem capital of abyssal plains, seamounts, and hydrothermal vents in the Area.

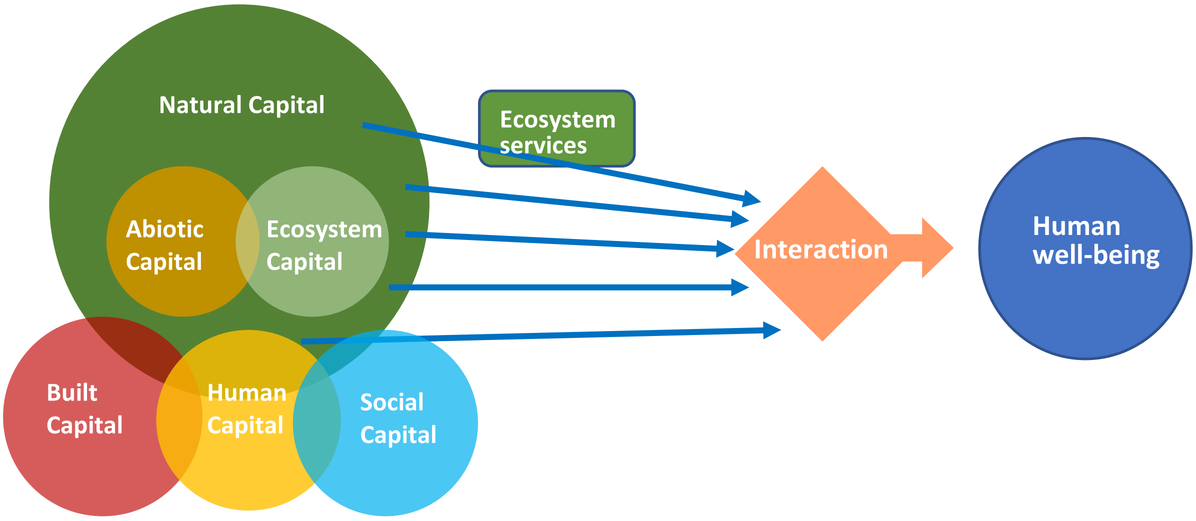

Figure 3. Interactions between natural, abiotic, ecosystem, built, human and social capital to contribute to human well-being. Adapted from Costanza *et al.* (2014).

3. The case for valuation of ecosystem services

3.1 The case for valuation of ecosystem services

The rationale for valuation of ecosystem services to support decision making is as follows. Ecosystem services contribute substantially to human welfare and in some cases are fundamental to sustaining life (e.g. climate regulation, nutrient recycling). The natural capital from which these services flow is, however, finite and cannot necessarily be regenerated or replaced. With growing human populations and consumption per capita increasing over time, it is highly likely that human use of natural resources will outstrip their availability (i.e. human use of the environment will be unsustainable). These simple realities of resource limitation mean that choices have to be made between alternative uses of available resources; and every time a decision is made to do one thing, this is also a decision not to do another. In other words, values on each option are being implicitly applied. This valuation is unavoidable and is the essence of decision making. So if valuation of alternative resource uses is unavoidable in making decisions, it is arguably better to make these values explicit and ensure that they are well informed in order to aid decision making. The valuation of ecosystem services attempts to do this.

3.2 The case for economic valuation

Economic value is simply a means to describe how important the things we use are to us, including our use of natural capital. In the case of ecosystem services provided by biotic natural capital in the Area, there are often no prices that reflect their value, since the services that are provided are not traded in markets (e.g. climate regulation, biodiversity). As a result, the value of these ecosystem services are not taken into consideration when we undertake activities that impact this environment. When we investigate the consequences of environmental change (e.g. due to mining activities) we need to fully understand the effects on ecosystem services and human well-being. Economic valuation tries to measure the importance of environmental change, usually in monetary terms, in order to communicate the scale of impacts to human well-being. Such information can be used to raise awareness of the economic importance of marine ecosystems, set fees for the use of marine ecosystem services, or determine compensation payments for environmental damage.

Economic valuation of ecosystem services involves identifying and quantifying the contribution of environmental resources to human well-being; and incorporating this information into decision-making and the design of policy instruments.

Economic valuation methods do not stand alone but are often used in combination with other methods for assessing environmental change and the provision of ecosystem services. The added value of using economic valuation methods is that the importance of ecosystem services is expressed in terms of human welfare and measured in common units (i.e. money), allowing values to be aggregated across ecosystem services and directly compared with the values of other costs and benefits of investments and policies.

3.3 Decision-making contexts that potentially use information on ecosystem service values

There are many decision-making contexts in which information on the value of coastal and marine ecosystems may be useful, including to:

– Raise ***awareness*** of the value of the marine environment. Estimates of the value of ecosystems can highlight its importance to the public and to policy makers;

– Design effective ***policy instruments*** for environmental management. Resource use and polluting activities affecting marine ecosystems can be managed using policy instruments such as operating standards, taxes, and compensation payments;

– Design mechanisms for ***sustainable financing***, including setting appropriate *fees* for use of ecosystem services. This is relevant to sustain financing for resource management after initial project funding ends;

– **Compare *costs and benefits*** of alternative uses of the environment. This may be done, for example, in the context of deep-sea mining to evaluate the net benefits from alternative activities;

– Reveal the ***distribution of costs and benefits*** of resource management decisions among different stakeholders. Transparently measuring who incurs the costs and who receives the benefits of resource management provides key information for decision makers;

– Include ecosystem service values in ***green accounts*** with the aim of measuring the importance of natural capital to the economy; and

– **Set *compensation for environmental damage***. Information on the full costs of mining activities can be used to determine the level of compensation that needs to be paid.

3.4 Limitations and criticisms of ecosystem valuation

The concept of ecosystem services provides a useful framework for identifying and quantifying the benefits that humans derive from nature. There are, however, a number of limitations to the effective implementation of this framework and criticisms of attempting to value ecosystem services.

The limitations or barriers to implementing the ecosystem service approach include:

- Lack of knowledge and understanding of the underlying state and functioning of ecosystems. The bio-physical relationships between ecosystem functioning and the provision of ecosystem services are often not well understood and are characterized by high uncertainties. Similarly, the understanding of long-run impacts, sustainability, positive and negative feedbacks and thresholds effects is limited. An understanding of such relationships, however, is fundamental to determining how policy and investment decisions that affect natural capital stocks and ecosystem functioning will filter through to changes in the flow and value of ecosystem services.
- A related challenge in assessing ecosystem services is due to the complexity of trade-offs between different ecosystem services. In many cases, the level of sustainable activity for one ecosystem service may not be compatible with the sustainable level of another. For example, trade-offs have been observed between fisheries and tourism sectors in which restricting one, benefits the other. Such trade-offs introduce further complexity to any analysis since it becomes necessary to consider how the one use of a marine resource affects other potential uses. This, however, can also be seen as a strength of the ecosystem service framework in that is enables these trade-offs to be explicitly analysed.
- Ecosystem service assessments are resource intensive and time consuming. The physical and social scientific methods applied to assess ecosystem services are sophisticated, time consuming and often expensive to implement. Assessment methods generally require extensive data, which may not be available especially for small scale studies. Moreover, the necessary technical expertise to conduct valuation studies is often lacking in the agencies that are responsible for environmental protection and resource management.

The criticisms and potential risks of the ecosystem service approach include:

- Quantification and valuation of ecosystem services may lead to their commodification (the transformation of something e.g. goods, services, nature etc. into commodities or objects of trade) that can then be sold. Many ecosystem services are public goods that beneficiaries enjoy without any charge for their use. There is concern that the process of quantifying the value of such services is a step towards setting prices for them and requiring beneficiaries to pay. Such a development potentially represents a transfer of wealth from beneficiaries to resource owners.
- The explicit identification of resource owners, custodians, users, and beneficiaries can raise questions of property rights, tenure and conflict. The tenure or property rights to many natural resources remains unassigned. For society, this can be both a positive characteristic from the perspective that such resources are open to all, or a negative characteristic from the perspective that such resources tend to be over-exploited. A potential risk in applying an ecosystem service approach is that issues of resource ownership become sources of conflict between different stakeholders.
- Valuation of ecosystem services can lead to changes in the management of natural resources to favour the highest value uses, to the detriment of lower valued uses. Without sufficient and appropriate compensation, this can have major distributional consequences across stakeholders for cases in which ES are used by different beneficiary groups.

- The framing of ecosystem services as nature's contributions to people is contrary to traditional understanding of the relationship between humans and the environment in some cultures and can disrupt traditional approaches to managing common natural resources. The concept of humans as recipients of benefits from nature, as opposed to part of the natural system, might be at odds with some indigenous and traditional systems of managing natural resources even to the point that it alters the effectiveness of such systems.
- The ecosystem service approach narrows the conception of the value of nature to anthropocentric or utilitarian values. The concept of nature having intrinsic value irrespective of any benefits it contributes to people does not fit in the ecosystem services framework.

4. Ecosystem valuation methods

A variety of methods have been developed for quantifying the importance of ecosystem services. These valuation methods are designed to span the range of complex interactions between the natural environment and people. The intention of the present guidance report is to provide an understanding of which valuation method can be used to value the key ecosystem services provided by habitats in the Area, and explain the key strengths, limitations, and data requirements of each method. For selected methods, the main steps in conducting a valuation are explained in Method Boxes in the following sections. It is beyond the scope of the report, however, to provide a complete manual on how to apply each valuation method. Indeed, some methods are highly technical, require advanced expertise and have lengthy manuals devoted to explaining their application. In this section, the distinction between bio-physical, social and economic approaches to measuring the value of ecosystem services is explained. Table 2 summarises the broad strengths and weaknesses of each set of methods.

Bio-physical approaches use data and models to assess the physical provision of ecosystem services. They generally focus on the righthand side of the ecosystem services cascade (see Figure 2) and measure the supply of services. Ecosystem service values are expressed in physical units or indicators (e.g. stocks of fish, extent and condition of ecosystems, etc.).

Social approaches use surveys, interviews, dialogues, workshops and other participatory approaches to collect data on people's perceptions and preferences for ecosystem services. Social methods express the value of ecosystem services in a variety of qualitative and quantitative terms.

Economic approaches use data on activities and expenditure by beneficiaries or collect data through surveys to elicit people's preferences and willingness to pay (WTP) for ecosystem services. Ecosystem service values are usually expressed in monetary units but can be expressed in other units that households value and allocate to alternative uses (e.g. time).

It is important to note that bio-physical, economic and social valuation methods are not mutually exclusive but more often provide complementary information on the importance of ecosystem services. Individual methods within each of these categories are introduced in the following sub-sections, with a more in-depth focus on economic valuation methods.

Table 2. Summary of bio-physical, economic and social valuation methods.

Method	Approach	Strengths	Weaknesses
Bio-physical	Quantifies physical variables that determine or indicate the provision of ecosystem services.	+ Uses a variety of objective, data-based, scientific methods to quantify ecosystem services in physical units. + Generalized models for most ecosystem services are available.	- High technical and data requirements. - Focuses on supply side without reflecting demand for ecosystem services. - Some ecosystem services are difficult to value in physical units (e.g. aesthetic enjoyment). - Physical units for different ecosystem services cannot be easily aggregated or compared.

Method	Approach	Strengths	Weaknesses
Social	Measures the perception of ecosystem services and their contribution to human well-being in non-monetary (qualitative and quantitative) units.	+ Participatory methods aid learning and knowledge production. + Enables measurement of multiple value concepts. + Elicited values are not constrained by monetary income/wealth.	- Different units of measurement of different ecosystem services and value concepts cannot be easily aggregated or compared. - Methods can be manipulated and subject to bias.
Economic	Estimates the contribution of ecosystem services to human well-being, usually measured in monetary units.	+ With money as a unit of measurement of different ecosystem services, values can be aggregated and directly compared to other values that are relevant to decision makers.	- Some methods have high technical and data requirements. - Some ecosystem services are difficult to value in monetary terms (e.g. biodiversity existence). - Use of money as a unit of measurement is repugnant to some stakeholders. - Elicited values can be constrained by monetary income/wealth and therefore aggregate results can disproportionately reflect the preferences of wealthy beneficiaries.

4.1 Bio-physical valuation methods

Biophysical methods for measuring the importance of ecosystem services are based on quantification of different parameters of biotic and abiotic structures that determine the provision of ecosystem services. Biophysical quantification is built on spatial and temporal measures of ecosystem processes. Following Vihervaara *et al.* (2018), biophysical methods are grouped into three categories distinguished by the character of the measurements and how the information is extracted: 1. Direct measurements; 2. Indirect measurements; 3. Modelling (see Figure 4).

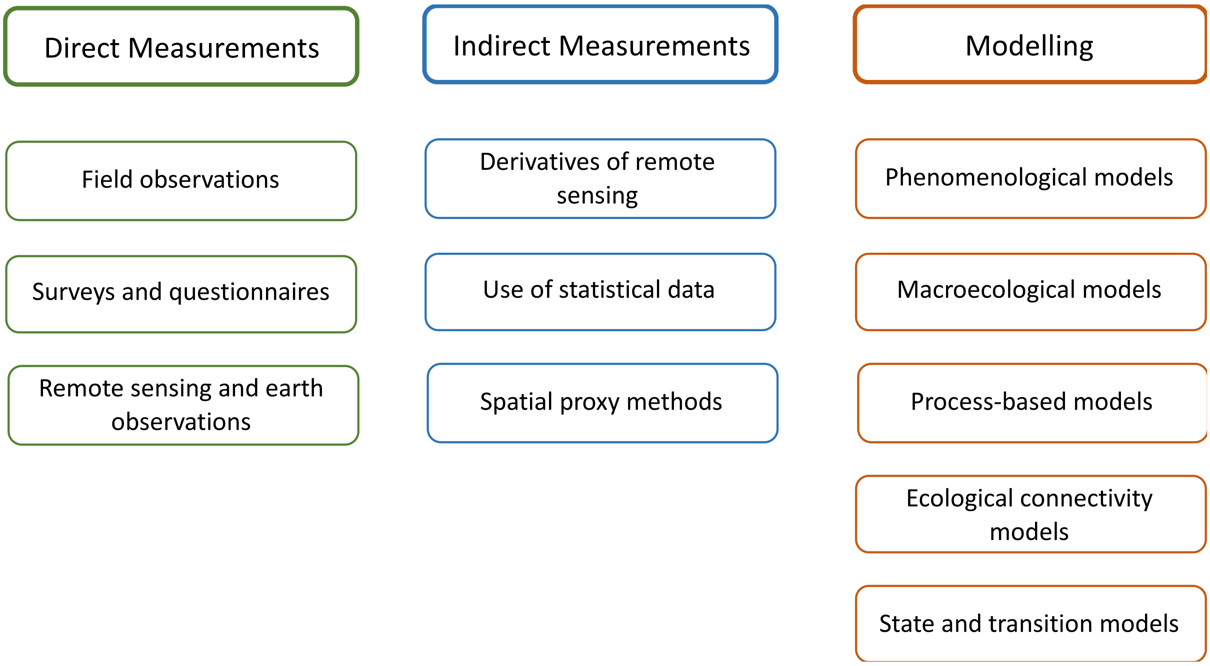

Figure 4. Overview of bio-physical valuation methods.

Direct measurement methods of ecosystem services are the measurements of a state, a quantity, or a process from ecosystem observations, monitoring, surveys, questionnaires, or data from remote sensing and earth observations, which cover the entire study area in a representative manner. Direct measurements deliver a biophysical value of an ecosystem service in physical units that correspond to the units of the indicator and quantify or measure a stock or a flow value. Direct measurements are also used as primary data for other methods, as they are one of the most accurate ways to quantify ecosystem services. However, they are often impractical and expensive beyond the site level, and therefore are usually used as an input for other biophysical mapping methods or to validate certain mapping and assessment elements. In many cases, direct measurements are simply not available for all ecosystem services.

Indirect measurement methods rely on the use of different data sources to measure biophysical values in physical units, but such values need further interpretation, assumptions, or data processing before they can be used. Indirect measurements can be based on remote sensing and earth observation derivatives such as land cover, Normalized Difference Vegetation Index (NDVI), surface temperature, or soil moisture, which are extracted from the original sources by specific procedures. For example, land cover can be derived from remote sensing images through visual interpretation or automated classification, whereas NDVI is derived by measuring the difference of particular spectral bands. These methods are of less relevance to the measurement of deep-sea ecosystem services.

Modelling methods include several groups of modelling approaches from ecology (phenomenological, macro-ecological, trait-based), statistics, or other marine sciences fields. Conceptual models and integrated modelling frameworks are also included in this group.

4.2 Social valuation methods

Social valuation methods attempt to measure the relative importance of ecosystem services to people. As such, they also focus on the right-hand side of the ecosystem services cascade (see Figure 2). Social methods are distinct from economic methods in that they measure value in non-monetary units and enable a multi-dimensional conceptualisation of human well-being.

Social methods necessarily involve people in the valuation process and can be grouped into three broad categories in relation to how they engage stakeholders and elicit their perceptions and values (Santos-Martin *et al.*, 2018): 1. Observation methods; 2. Consultation methods; 3. Engagement methods (see Figure 7).

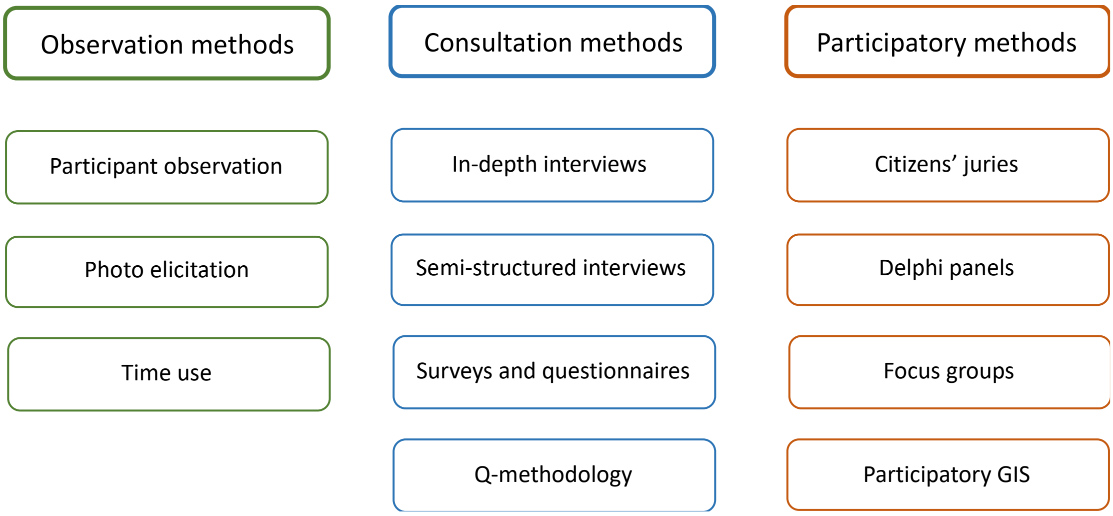

Figure 7. Overview of social valuation methods.

Observation methods involve the monitoring of stakeholders' behaviour by researchers and the analysis of social preferences and values. Observation methods generally yield quantitative measurement of values for ecosystem services. Examples of observation methods include the use of photographs posted to social media to infer preferences for natural features; or measurement of time allocated to different activities to measure relative recreational values.

Consultation methods are based on qualitative data that are usually obtained through an interactive process involving stakeholders and researchers. These methods make use of in-depth and semi-structured interviews that allow participants to express their motivations and diverse values for ecosystem services through their own stories and direct actions. These types of methods are usually applied to understand and describe the variety of motivations behind the social value that different stakeholders attribute to nature. Other examples of engagement methods are ranking and rating exercises, in which participants are asked to first rank ecosystem services in order of priority and then rate their relative importance by assigning a fixed number of units (e.g. 20 pebbles or beans) across the services (see Case Study 2 for an example application in Madagascar); and "photo and speech" approaches, in which stakeholders are given a camera and asked to photograph ecosystems and locations that are of importance to them, which are then shown and discussed with the researcher.

Engagement methods gather both qualitative and quantitative data through interactive processes involving stakeholders and researchers. These methods use participatory and deliberative (consultative) tools such as focus groups, citizens' juries, Delphi panels, and participatory GIS. Often these methods involve co-learning and knowledge co-production as they foster discussion between different stakeholder groups regarding trade-offs among different ecosystem services.

4.3 Economic valuation methods

Economic valuation methods include a wide range of approaches for estimating the contribution of ecosystem services to human well-being. As such, they focus on the right-hand side of the ecosystem services cascade (see Figure 2). The intention of the present guidance report is to provide an understanding of which valuation methods can be used to value the key ecosystem services provided by seabed habitats in the Area, and explain the key strengths, limitations and data requirements of each method. For selected methods, the main steps in conducting a valuation are explained in Methods Boxes. It is beyond the scope of this guidance report, however, to provide a complete manual on how to apply each valuation method. Indeed, some methods are highly technical, require advanced expertise and have lengthy manuals devoted to explaining their application.

Figure 5 provides a representation of the available economic methods for valuing ecosystem services. A first categorisation of methods is into "primary valuation methods" and "value transfer methods". The former methods produce new or original information generally using primary data whereas the latter methods use existing information from primary valuation studies and transfer it to estimate values at other locations, as described more fully below.

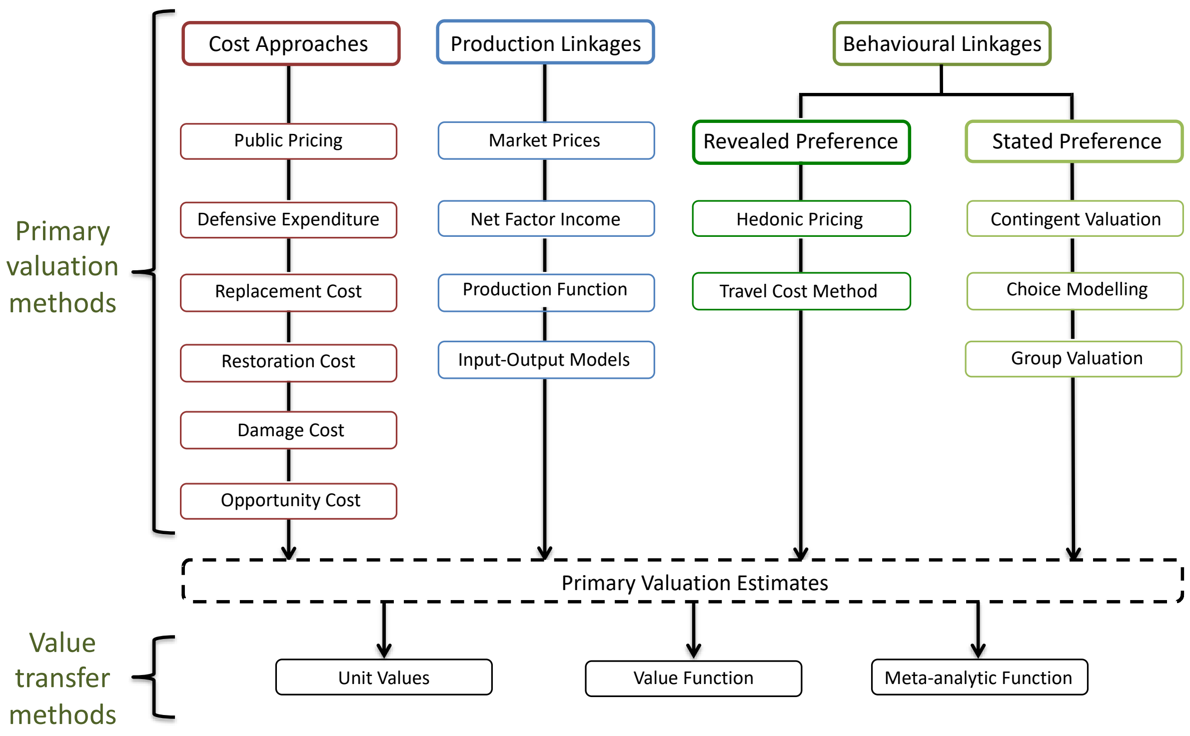

Figure 5. Overview of economic valuation methods. Source: Brander (2018).

The choice of which valuation method to use is determined to a large extent by which ecosystem services is being valued. The applicability of some valuation methods is limited to specific ecosystem services. Figure 6 illustrates this by drawing linkages between the set of ecosystem services that could potentially be impacted by mining activities, including services provided by seabed habitats in the Area and those provided by other ecosystems that could be affected by mining activities, and the valuation methods that are most applicable to value them.

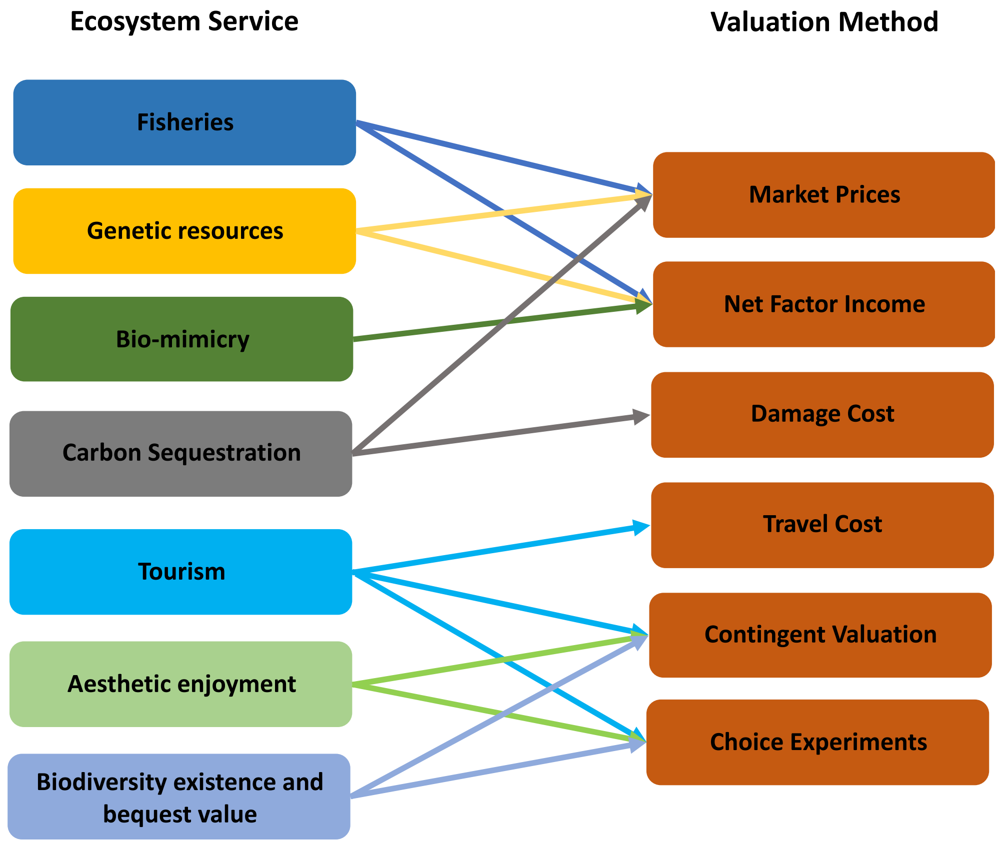

Figure 6: Linkages between ecosystem services that could potentially be impacted by seabed mining activities and relevant primary economic valuation methods. Adapted from Brander (2018).

4.3.1 Primary valuation methods

Primary valuation methods are those that produce new or original value information generally using primary data. Table 3 provides an overview of primary valuation methods, applicability to specific ecosystem services, limitations, and an indication of the approximate time required and relative cost of implementation. The estimated time and cost requirements are for the economic valuation analysis only and do not pertain to the biophysical modelling of impacts on ecosystem services. Moreover, given the lack of precedent valuation studies for deep sea ecosystem services, the estimated study times and costs are uncertain.

An important distinction between primary valuation methods is the difference between revealed preference methods (those that observe actual behaviour of the use of ecosystem services to elicit values) and stated preference methods (those that use public surveys to ask beneficiaries to state their preferences for, generally hypothetical, changes in the provision of ecosystem services). Revealed preference methods may be favoured since they reflect actual behaviour but are restricted in their applicability to a limited set of ecosystem services. Stated preference methods on the other hand rely on responses recorded in surveys or experiments but are more flexible in their application and can in principle be used to value any ecosystem service.

It should be noted that different valuation methods produce different measures of economic value that are not necessarily equivalent and cannot be directly compared. The valuation method, and the measure of economic value that it estimates, will have a substantial bearing on the magnitude of the value estimated. It is therefore important to understand what each measure is and to select a measure that is relevant to the case in hand. There are numerous existing publications that provide guidance on the use of primary valuation methods. A selection of useful guidance material is provided here:

- Defra (2007). An introductory guide to valuing ecosystem services. Department for Environment, Food and Rural Affairs (Defra).
- Defra (2013). Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services. Department for Environment, Food & Rural Affairs.
- Ecosystem Valuation. US Department of Agriculture Natural Resources Conservation Service and National Oceanographic and Atmospheric Administration (NOAA). http://www.ecosystemvaluation.org/uses.htm
- Freeman, A.M.I. (2003). The Measurement of Environmental and Resource Values. Resources for the Future, Washington D.C. https://www.rff.org/publications/books/the-measurement-of-environmental-and-resource-values/
- GEF IW:LEARN (2018). Global Environment Facility (GEF) Guidance Documents to Economic Valuation of Ecosystem Services in International Waters Projects. https://www.iwlearn.net/resolveuid/0ffc8834-af39-488a-852a-4348fee97b85
- GEF LME:LEARN (2018). Environmental Economics for Marine Ecosystem Management Toolkit. https://iwlearn.net/manuals/environmental-economics-for-marine-ecosystem-management-toolkit
- Johnston, R.J., Boyle, K.J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R. and Tourangeau, R. 2017. Contemporary guidance for stated preference studies. Journal of the Association of Environmental and Resource Economists, 4(2), 319-405.
- Koetse, M. J., Brouwer, R., and Van Beukering, P. J. (2015). Economic valuation methods for ecosystem services. Ecosystem services: From concept to practice, 108-131. https://doi.org/10.1017/CBO9781107477612.009
- OECD (2002) Handbook on Biodiversity Valuation. Organisation for Economic Cooperation and Development, Paris. https://doi.org/10.1787/9789264175792-en
- OECD (2018). Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris. https://doi.org/10.1787/9789264085169-en

- Salcone J., Brander, L.M. and Seidl, A (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.

  http://macbio-pacific.info/Resources/marine-ecosystem-services-valuation-in-the-pacific/

- VALUES (2021). Methods for integrating ecosystem services into policy, planning, and practice. http://www.aboutvalues.net/about_values/
- van Beukering, P., Brander, L., Tompkins, E., and Mackenzie, E. (2007). Valuing the environment in small islands: An environmental economics toolkit. Joint Nature Conservation Committee. http://jncc.defra.gov.uk/page-4065

Table 3. Primary valuation methods, applicability to ecosystem services, examples and limitations (adapted from Table A2, Brander 2013)

Valuation method	Approach	Data requirements and sources	Application to ecosystem services	Example ecosystem service	Limitations	Study time and cost
Market prices	Prices for ES that are directly observed in markets.	Prices of some ES can be obtained from markets or surveys of businesses and households.	ES that are traded directly in markets.	Fish; Carbon credits.	Market prices can be distorted e.g. by subsidies. Most ES are not traded in markets.	1-3 months $
Public pricing	Public expenditure or monetary incentives (taxes/subsidies) for ES as an indicator of value.	Data on public expenditures on the provision of ES obtained from government reports or key informants.	ES for which there are public expenditures.	Carbon sequestration valued using public expenditure on reducing greenhouse gas emissions	No direct link to preferences of beneficiaries.	1-3 months $
Defensive expenditure	Expenditure on protection of ES.	Data on public or private expenditure obtained from government reports, key informants, or surveys of businesses and households.	ES for which there is public or private expenditure for its protection.	Recreation and aesthetic values from marine protected areas.	Only applicable where direct expenditures are made for environmental protection related to provision on an ES. Provides lower bound estimate of ES benefit.	1-3 months $
Replacement cost	Estimate the cost of replacing an ES with a man-made service.	Estimates of infrastructure costs can be obtained from experts or based on past investments.	ES that have man-made equivalents.	Coastal protection by mangroves (replaced by seawalls)	No direct relation to ES benefits. Over-estimates value if society is not prepared to pay for man-made replacement. Under-estimates value if man-made replacement does not provide all of the benefits of the original ecosystem.	1-3 months $
Restoration cost	Estimate cost of restoring degraded ecosystems to ensure provision of ES.	Estimates of restoration costs can be obtained from experts or based on past investments.	Any ES that can be provided by restored ecosystems.	Tourism and aesthetic enjoyment provided by restored coral reefs	No direct relation to ES benefits. Over-estimates value if society is not prepared to pay for restoration. Under-estimates value if restoration does not provide all of the benefits of the original ecosystem.	1-3 months $

Valuation method	Approach	Data requirements and sources	Application to ecosystem services	Example ecosystem service	Limitations	Study time and cost
Damage cost avoided (see Method Box 1)	Estimate damage avoided due to ecosystem service.	Data on past damage costs and frequencies can be obtained from government reports and household surveys.	Ecosystems that provide protection to people and/or assets.	Coastal protection by mangroves and coral reefs; Carbon sequestration that mitigates climate change	Difficult to quantify changes in risk of damage to changes in ecosystem condition.	3-6 months $$
Social cost of carbon (SCC) (see Method Box 1)	The monetary value of damages caused by emitting one tonne of CO_2 in a given year. The social cost of carbon (SCC) therefore also represents the value of damages avoided for a one tonne reduction in emissions.	Estimates of the SCC can be obtained from Integrated Assessment Models of climate-economy impacts and published summaries of model results.	Carbon storage and sequestration.	Carbon sequestered and stored by microbes and stored in sediment at the sea floor.	SCC is a specific application of the "damage cost avoided" method. SCC is characterized by high modelling uncertainties and partial coverage of climate change impacts.	1-3 months $
Opportunity cost	The next highest valued use of the resources used to produce an ecosystem service.	Data on the value of alternative resource uses (e.g. mineral extraction) can be obtained from markets and surveys of operators.	All ecosystem services.	The opportunity cost of ecosystem services from a conserved seabed habitat might be the foregone value of mineral extraction.	Measures the cost of providing ecosystem services instead of the benefit.	1-3 months $
Net factor income (residual value)	Revenue from sales of a marketed good with an ES input minus the cost of other inputs.	Revenues can be obtained from markets; costs can be obtained from business surveys.	Ecosystems that provide an input in the production of a marketed good.	Commercial fisheries supported seabed habitats; Bio-mimicry of seabed organisms in technological developments.	Tendency to over-estimate values since all normal profit is attributed to the ES.	3-6 months $$

Valuation method	Approach	Data requirements and sources	Application to ecosystem services	Example ecosystem service	Limitations	Study time and cost
Production function	Statistical estimation of production function for a marketed good with an ES input.	Data on production, inputs, costs and revenues can be obtained from business surveys.	Ecosystems that provide an input in the production of a marketed good.	Commercial fisheries supported seabed habitats; Bio-mimicry of seabed organisms in technological developments.	Technically difficult. High data requirements.	6-12 months $$
Input-Output Models	Quantifies the interdependencies between economic sectors in order to measure the impacts of changes in one sector to other sectors in the economy. Ecosystems can be incorporated as distinct sectors.	Data on production inputs, outputs and prices for multiple economic sectors can be obtained from government statistics. Data on ecosystem inputs and outputs can be observed or modelled using bio-physical methods.	Ecosystem services with direct and indirect use values, particularly inputs into production.	Ecosystem inputs into fisheries; or into the tourism sector.	Requires substantial data on ecosystem-economy linkages to parameterise connections between sectors.	6-12 months $$
Hedonic pricing	Estimate influence of environmental characteristics on price of marketed goods (usually residential property).	Data on house prices and characteristics can be obtained from estate agents or public records. Data on environmental characteristics can be observed or modelled using bio-physical methods.	Environmental characteristics that vary across goods (usually houses).	Air quality moderated by ecosystems.	Technically difficult. High data requirements. Limited to ES that are spatially related to property locations.	6-12 months $$
Travel cost	Estimate demand for ecosystem recreation sites using data on travel costs and visit rates.	Data on travel costs and visit rates can be obtained through visitor surveys.	Recreational use of ecosystems.	Dive tourism at coral reefs	Technically difficult. High data requirements. Limited to valuation of recreation. Complicated for trips with multiple purposes or to multiple sites.	6-12 months $$$

Valuation method	Approach	Data requirements and sources	Application to ecosystem services	Example ecosystem service	Limitations	Study time and cost
Contingent valuation (see Method Box 2)	Ask people to state their WTP for an ES through surveys.	Data collected through public surveys.	All ecosystem services.	Existence and bequest values for biodiversity; Tourism and recreation	Expensive and technically difficult to implement. Risk of biases in design and analysis.	6-12 months $$
Choice modelling (choice experiment) (see Method Box 3)	Ask people to make trade-offs between ES and other goods to elicit WTP.	Data collected through public surveys.	All ecosystem services.	Existence and bequest values for biodiversity; Tourism and recreation	Expensive and technically difficult to implement. Risk of biases in design and analysis.	6-12 months $$$
Group / participatory valuation	Ask groups of stakeholders to state their WTP for an ES through group discussion.	Data collected in workshop settings.	All ecosystem services.	Existence and bequest values for biodiversity; Tourism and recreation	Risk of biases due to group dynamics.	6-12 months $$$

Methods Box 1. Damage cost avoided

The damage cost avoided method can be used to estimate the economic value of the role ecosystems play in mitigating damage to assets, infrastructure and people. Example applications include the reduction in storm damage attributable coastal ecosystems such as mangroves and coral reefs; the reduction in river flood damages due to the regulation of water flows by upstream wetlands and forests; and the mitigation of climate change damage provided by phytoplankton that sequester and store carbon.

The damage reduction benefits of an ecosystem can be determined by comparing risk between two situations: with the ecosystem and without the ecosystem. The general approach to applying the damage cost avoided method follows four steps (adapted from van Zanten et al (2023):

1. Estimate hazard intensity without the ecosystem. The effects of a natural hazard can be estimated based on a description of the hazard intensity (e.g., flood depth or extent) with the probabilities of occurrence, based on historic observations and/or statistical and numerical modeling.
2. Estimate the effects of the ecosystem on hazard intensity. The effect of the ecosystem can be determined by including the effects of natural features in the hazard models to assess changes in the hazard intensity.
3. Assess expected economic effects with and without the ecosystem. This assessment requires calculating exposure and vulnerability through damages to buildings, infrastructure, changes in yields, uses, agricultural land, people affected, and other assets relevant for the project.
4. Compute the benefits of ecosystem protection. This is calculated as the difference in the total damages between the scenarios with and without ecosystem protection.

The social cost of carbon (SCC) is a specific application of the damage cost avoided method to value greenhouse gas sequestration and emissions. The SCC is the monetary value of damages caused by emitting one additional 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. 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 (Rennert et al., 2022). Estimates of the SCC are diverse depending on the included impact categories, modelling assumptions and discount rate, and generally in the range US$ 50-100 tCO_2 (Tol, 2023).

Seabed habitats and the water column above are home to a diverse range of species that sequester carbon through photosynthesis and the production of calcium carbonate shells, which contribute to carbon storage in substrate at the seabed. The rates at which carbon is added to biomass/substrate (sequestration rate) and released can be used to calculate the net change in atmospheric carbon dioxide, in a given time period. We note that current understanding of these processes in seabed habitats and the water column, and the extent to which they are impacted by mineral exploitation, is highly uncertain and that quantification of impacts on carbon is therefore challenging.

The main steps in applying the social cost of carbon to value sequestration and storage by marine ecosystems are:

1. Estimate the change in atmospheric carbon following a disturbance to the marine

ecosystem.

1.1. Compute the foregone sequestration of carbon due to the disturbance. This requires information on the annual sequestration rate of each ecosystem and quantitative understanding of how this changes as the result of the disturbance.

1.2. Compute the quantity of stored carbon released to the atmosphere. This requires information on the rates at which stored carbon is released following a disturbance. The release of stored carbon is not instantaneous and may occur over a prolonged period of time.

Note that the observed price in carbon markets reflects the value to the resource owners (i.e. what price can they sell their carbon for), whereas the social cost of carbon represents the global benefits of sequestering and storing carbon.

Source: Adapted from Salcone *et al.* (2016) and Brander (2018)

Methods Box 2 Contingent valuation

Contingent valuation is a stated preference method and involves directly asking people, in a survey, how much they would be willing to pay for specific changes in the provision of ecosystem services. The underlying idea behind this method is that a hypothetical, yet realistic, market for buying or selling the use and/or conservation of an ecosystem service can be described in detail to an individual, who then participates in the hypothetical market by responding to a series of questions. These questions relate to a proposed change in the provision or quality of the ecosystem service.

Contingent valuation may be a useful valuation method in the context of ecosystem services from seabed habitats given its flexibility for valuing the full range of ecosystem services. It may be particularly relevant for valuing existence and bequest values for the conservation of biodiversity. This method can, however, involve complex data analysis and relatively expensive data collection.

The main steps in applying the contingent valuation method are:

Step 1. Define the policy issue in terms of the ecosystem services that need to be valued and the relevant population of beneficiaries.

Step 2. Design the survey. This involves a number of steps including deciding what type of survey will be used (mail, telephone, face-to-face, internet) and developing the sampling strategy.

Step 3. Develop the questionnaire. This involves deciding on question formats, description of the ecosystem service to be valued, payment method and WTP question. Test the questionnaire on focus groups and/or small samples and adjust if necessary.

Step 4. Survey implementation. This includes recruiting and training enumerators, pilot testing the questionnaire and adjusting if necessary, full sampling, and data entry.

Step 5. Analysing the results. This includes cleaning the data and dealing with non-responses and protest bids. Mean WTP for the sample of respondents can be calculated and extrapolated to the relevant population of beneficiaries to estimate a total value for the ecosystem service.

Source: Adapted from van Beukering *et al.* (2007)

Methods Box 3. Choice modelling

Choice modelling or choice experiments is a stated preference method in which a public survey is used to elicit the preferences or values of respondents for specified changes in a good or service. Choice modelling is widely used in market research and economics to obtain information on public preferences that are otherwise not observable in consumer behaviour.

Choice modelling may be a useful valuation method in the context of ecosystem services from seabed habitats given its flexibility for valuing the full range of ecosystem services. It may be particularly relevant for valuing existence and bequest values for the conservation of biodiversity. This method can, however, involve complex data analysis and relatively expensive data collection.

In practical terms, a choice model valuation involves asking survey respondents to make repeated choices between alternative multi-attribute descriptions of a good or service. By observing the trade-offs that are made between attributes, it is possible to estimate their relative values. By including one attribute that represents a monetary payment on the part of the respondent it is possible to compute the WTP for changes in the other attributes.

The main steps in conducting a choice modelling valuation are:

Step 1. Define the policy issue in terms of the ecosystem services that need to be valued and the relevant population of beneficiaries.

Step 3. Designing the choice sets. This involves selecting the ecosystem service attributes to be valued and the payment method attribute, defining the levels used to describe each attribute, generating a statistical or experimental design that determines the combinations of attribute levels shown in each option on each choice card, and building the choice cards that will be shown to respondents.

Step 3. Develop the questionnaire. This involves drafting questions regarding use/knowledge of the ecosystem services to be valued, background socio-economic characteristics of respondents, and follow-up questions on the choice process and motivations. Test the questionnaire, including the choice cards, on focus groups and/or small samples and adjust if necessary.

Step 4. Survey implementation. This involves a number of steps including deciding what type of survey will be used (mail, telephone, face-to-face, internet), developing the sampling strategy, recruiting and training enumerators, pilot testing the questionnaire and adjusting if necessary, full sampling, and data entry.

Step 5. Analysing the results. This includes cleaning the data and dealing with non-responses and protest bids. Choice data is generally analysed using multinomial logit regressions to estimate marginal utilities for each ecosystem service attribute and the payment vehicle. Mean WTP per respondent can be calculated by computing the ratio of the marginal utility of ecosystem service to the marginal utility of money – and extrapolated to the relevant population of beneficiaries to estimate a total value for the ecosystem service.

Henscher et al. (2015) provide a technical guide to the applied choice analysis.

Source: Adapted from van Beukering *et al.* (2007).

4.3.2 Value transfer methods

Decision-making often requires information quickly and at low cost. New 'primary' valuation research, however, is generally time consuming and expensive. For this reason, there is interest in using information from existing primary valuation studies to inform decisions regarding impacts on ecosystems that are of current interest. This transfer of value information from one context to another is called "value" or "benefit transfer".

Value transfer is the use of research results from existing primary studies at one or more sites ("study sites") to predict welfare estimates or related information for other sites; in the context of seabed mining activities we term these ("activity sites"). Value transfer is also known as benefit transfer but since the values that are transferred may be costs as well as benefits, the term value transfer is more generally applicable.

In addition to the need for expeditious and inexpensive information, there is often a need for information on the value of ecosystem services at a different geographic scale from that at which primary valuation studies have been conducted. So even in cases where some primary valuation research is available for the ecosystem of interest, it is often necessary to extrapolate or scale-up this information to a larger area or to multiple ecosystems in the region or country. Primary valuation studies tend to be conducted for specific ecosystems at a local scale whereas the information required for decision-making is often needed at a regional or multi-national scale. Value transfer therefore provides a means to obtain information for the scale that is required.

For most terrestrial and coastal biomes, the number of primary studies on the value of ecosystem services is substantial and growing rapidly (Brander et al., 2023, forthcoming). This means that there is a growing body of evidence to draw on for the purposes of transferring values to inform decision-making. With an expanding information base, the potential for using value transfer is improved. In the case of ecosystem services from seabed habitats in the Area, however, the available number of economic valuation studies is very low and the potential for using value transfer methods is limited until further primary valuations are available. See Brander and Guisado Gõni (2023) for an overview of existing valuation studies are for deep-sea ecosystems.

Value transfer can potentially be used to estimate values for any ecosystem service, provided that there are primary valuations of that ecosystem service from which to transfer values. Value transfer methods have been employed widely in national and global ecosystem assessments, value mapping applications and policy appraisals. The use of value transfer is widespread but requires careful application. The alternative methods of conducting value transfer are described here:

1. **Unit value transfer** uses values for ecosystem services at a study site, expressed as a value per unit (usually per unit of area or per beneficiary), combined with information on the quantity of units at the activity site to estimate activity site values. Unit values from the study site are multiplied by the number of units at the activity site. Unit values can be adjusted to reflect differences between the

study and activity sites (e.g. income and price levels). (see Method Box 4 for more details on the main steps).

2. **Value function transfer** uses a value function estimated for an individual study site in conjunction with information on parameter values for the activity site to calculate the value of an ecosystem service at the activity site. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Value functions can be estimated from a number of primary valuation methods including hedonic pricing, travel cost, production function, contingent valuation and choice experiments.
3. **Meta-analytic function transfer** uses a value function (see above) estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the activity site to calculate the value of an ecosystem service at the activity site. Since the value function is estimated from the results of multiple studies it is able to represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics. This feature of meta-analytic function transfer provides a means to account for simultaneous changes in the stock of ecosystems when estimating economic values for ecosystem services (i.e. the "scaling up problem"). By including an explanatory variable in the data describing each "study site" that measures the scarcity of other ecosystems in the vicinity of the "study site", it is possible to estimate a quantified relationship between scarcity and ecosystem service value. This parameter can then be used to account for changes in ecosystem scarcity when conducting value transfers at large geographic scales. (see Method Box 5 for more details on the main steps).

These three principal methods for transferring ecosystem service values are summarized in Table 4 together with their respective strengths and weaknesses. The choice of which value transfer method to use to provide information for a specific policy context is largely dependent on the availability of primary valuation estimates and the degree of similarity between the study and activity sites. In cases where value information is available for a highly similar study site, unit value transfer may provide the most straightforward and reliable means of conducting value transfer. On the other hand, when study sites and activity sites are different, value function or meta-analytic function transfer offers a means to systematically adjust transferred values to reflect those differences. Similarly, in the case that value information is required for multiple different activity sites, value function or meta-analytic function transfer may be a more accurate and practical means for transferring values. Using meta-analytic functions that include a parameter for ecosystem scarcity provides a means to account for simultaneous changes in the stock of ecosystem on the value of all ecosystem services (i.e. more accurately "scale-up" ecosystem service values).

Table 4. Value transfer methods, strengths, weaknesses (adapted from Table 3, Brander 2013)

Method	Approach	Strengths	Weaknesses
Unit value transfer	Select appropriate values from existing primary valuation studies for similar ecosystems and socio-economic contexts. Adjust unit values to reflect differences between study and activity sites (usually for income and price levels).	Simple	Unlikely to be able to account for all factors that determine differences in values between study and activity sites. Value information for highly similar sites is rarely available.
Value function transfer	Use a value function derived from a primary valuation study to estimate ES values at activity site(s).	Allows differences between study and activity sites to be controlled for (e.g. differences in population characteristics).	Requires detailed information on the characteristics of activity site(s).
Meta-analytic function transfer	Use a value function estimated from the results of multiple primary studies to estimate ES values at activity site(s).	Allows differences between study and activity sites to be controlled for (e.g. differences in population characteristics, area of ecosystem, abundance of substitutes etc.). Practical for consistently valuing large numbers of activity sites.	Requires detailed information on the characteristics of activity site(s). Analytically complex.

Methods Box 4. Unit value transfer

Unit value transfer uses primary valuation estimates for ecosystem services at a study site, expressed as a value per unit (usually per unit of area or per beneficiary), combined with information on the change in quantity of units at the activity site to estimate activity site values. Value per unit at the study site is multiplied by the relevant number of units at the activity site. The main steps in conducting a unit value transfer are:

Step 1. Conduct a literature search to identify primary valuation studies for study sites that are as similar as possible to the activity site in terms of ecosystem type and condition, level of ecosystem provision, and beneficiary population and characteristics.

Step 2. From the selected study site valuation results, obtain or compute the value per unit (e.g. US$ per household, US$ per visit, US$ per hectare, US$ per cubic meter water). The unit value may be from a single study site valuation or the average unit value from multiple study sites.

Step 2. Where necessary and feasible, adjust the study site unit value to reflect any identified differences between the study site(s) and the activity site. Common adjustments are for differences in incomes or price levels between the study and activity sites.

Step 3. For the activity site, quantify the change in ecosystem service provision in the units in which the transfer is being made (e.g. visits, hectares, cubic meters of water).

Step 4. Multiply the unit value by the change in units at the activity site to estimate the aggregate change in ecosystem service value.

Methods Box 5. Meta-analytic function transfer

Meta-analytic function transfer uses a value function estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the activity site(s) to calculate the value(s) of ecosystem services at the activity site(s). The main steps in conducting a meta-analytic function transfer are:

Step 1. Obtain or estimate a meta-analytic value function for the ecosystem service of interest. There are numerous published meta-analyses in the economic valuation literature for different ecosystems and ecosystem services from which value functions can be obtained. Alternatively, a new meta-analysis for the ecosystem service of interest can be conducted. The main steps in conducting a meta-analysis of primary valuation results in order to estimate a value function are:

a) From the available primary valuation studies, construct a database containing information on the value of the ecosystem service of interest.

b) Value information presented in the primary valuation literature may be reported in different physical and temporal units. Values need to be standardized into the same set of units (e.g. US$ per household per month, US$ per hectare per year) so that they can be directly compared and analysed. Similarly, value estimates are likely to be reported in different currencies and for different years and price levels. Values should therefore be standardized to the same currency, year of value/price level. In addition, value estimates produced using different primary valuation methods may estimate different concepts of value and may therefore not be directly comparable. If there is a sufficiently large number of primary value estimates available, it is preferable to only use estimates produced by the same primary valuation method. If this is not possible, variables should be included in the meta-analysis regression model to control for methodological differences between value estimates.

c) For each primary value estimate included in the database, include information on the valuation method used, type of ecosystem service valued, base level of provision, change in provision, characteristics of the ecosystem (e.g., size, condition), and the characteristics of beneficiaries (e.g., number, household size, income, age).

d) In addition to information obtained directly from each primary study, information on each study site can be added using secondary data sources including spatially defined data using Geographic Information System (GIS). Examples of such additional data include population density, income, abundance of other ecosystems in the vicinity of the study site, landscape fragmentation, and distance to population centres.

e) Estimate a multiple regression equation with the standardized value as the dependent variable and measures of study, ecosystem and beneficiary characteristics as explanatory variables.

Step 2. Collect information for the activity site(s) on each of the parameters (explanatory variables) in the meta-analytic value function and for the quantity of units in which the dependent variable is defined (e.g. number of households, hectares of ecosystem).

Step 3. Input the activity site parameter values into the meta-analytic value function to estimate the unit value(s) of the ecosystem service at the activity site(s).

Step 4. Multiply the estimated unit value(s) by the number of units at the activity site(s) to compute the value of the ecosystem service at the activity site(s).

4.4 Important considerations: distribution, discounting, double-counting and uncertainty

4.4.1 Distribution of impacts across stakeholders

The distribution of costs and benefits across different groups in society is usually an important criterion in public decision-making and needs to be addressed as part of the valuation process. The allocation of the benefits and costs among different groups within society may well determine the political acceptability of alternative options.

The uneven distribution of costs and benefits has both practical and ethical consequences. In practical terms, it is important to assess the burden of costs and benefits received by local stakeholders, as they often have a strong influence on how successful project implementation will be. For example, the establishment of protected areas that attempt to exclude local stakeholders from accessing an environmental resource will not be successful without sharing the benefits of conservation with them. Understanding who gains and who loses from environmental change or management can provide important insights into the incentives that different groups have to support or oppose policy options.

In terms of ethical considerations, the analysis of the distribution of costs and benefits is important to ensure that conservation interventions do not harm vulnerable groups within society. Identifying and estimating the distribution of costs and benefits across different groups is the first step in designing measures to avoid disproportionate or undesirable allocation of impacts, compensation mechanisms, or payment schemes between gainers and losers. A general approach to identifying which groups will be affected by alternative options is through stakeholder analysis. One way of displaying the distributional effects is to construct a distributional matrix, which displays the impacts of environmental change, and indicates how they are distributed among different socio-economic groups.

4.4.2 Spatially distributed impacts

The management of ecosystem services is often one of spatial targeting. Decisions are being made about where to locate resource extraction, invest in ecosystem restoration, or establish protected areas. In such cases, the spatial distribution of ecosystem services is relevant to the decision and mapping this information is necessary. Alternative investment and policy options will generally result, not only in different aggregate costs and benefits, but also in the spatial distribution of impacts. If these differences in spatial distribution are considered of importance, they also need to be represented to decision makers. The analysis of the spatial distribution of values may be seen as an extension of the distributional analysis described in the previous section and may be a useful approach to identifying different societal groups that are impacted by a project.

4.4.3 Temporally distributed impacts

Mining activities in the Area are likely to result in changes in the flow of ecosystem services not only in the year in which the activity takes place but also over a number of years into the future. Resulting changes in the flow of ecosystem service values will therefore have a temporal distribution. It is important to account for this distribution of ecosystem services over time because people tend to place higher importance on values received in the present compared to values received in the future. The practice of accounting for this time preference is called discounting and involves putting a higher weight on current values.

There are two motivations for this higher weighting of current values. The first is that people are impatient and simply prefer to have things now rather than wait to have them in the future. The second reason is that, since capital is productive, a dollar's worth of resources now will generate more than a dollar's worth of goods and services in the future. Therefore, an entrepreneur is willing-to-pay more than one dollar in the future to acquire one dollar's worth of these resources now. In most cases, the discount rate is therefore based on the opportunity cost of capital – the prevailing rate of return on investments elsewhere in the economy, i.e. the interest rate.

The usual way to deal with temporally distributed values is to apply a discount rate to future values so that they can be compared as "present values". Suppose that an annual value X of an ecosystem service will occur over a period of T years, and a discount rate of r percent is applied, then the present value of the ecosystem service is:

$$\sum_{t=0}^{T} X / (1+r)^t$$

The present value of the value X in any given future year, is smaller than the value X in year t=0. From the equation it can be seen that the higher the discount rate r and the higher the number of years (t), the lower the discounted value of future benefits in any given year.

The choice of the appropriate discount rate remains a contentious issue because it places low weight on impacts that occur in the future and can have a significant influence on the outcome of the analysis (see Pearce, 2003; Khan and Green, 2013). Various respected organisations provide advice on the discount rate to be used. For example, the UK Treasury guidelines recommend a discount rate of 6 percent for public sector projects while for most environmental and social impact studies 3.5 percent is recommended (see UK Treasury, 2018).

There is evidence to suggest that people discount the future differently for different goods. If people have lower rates of time preference for environmental goods than for money, a lower discount rate than the interest rate should be used. It is also possible that rates of time preference diminish over time, i.e. that the discount rate declines for impacts in the far future. The choice of discount rate can have a large influence on the findings of an evaluation or valuation study and should therefore be varied in a sensitivity analysis to check how it affects the results.

4.4.4 Assessing and communicating uncertainty

The magnitude of uncertainty regarding estimated values needs to be quantified and communicated in order to provide an understanding of the robustness of the value information provided. Decision makers can then assess whether the information is sufficiently precise to be considered in making decisions. 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 an estimated value) and too much information that cannot be understood (e.g. a table of alternative results from an extensive sensitivity analysis).

Alternative ways to quantify and communicate uncertainties in estimated values include:

1. **Ranges of values**. In cases where multiple primary value estimates are available for the ecosystem service under consideration, the range of values can be presented to give an impression of the variability of unit value estimates.
2. **Distribution of values**. In order to give a more complete picture of the distribution of value estimates, information on the average, median and standard error of the average value can be presented (in addition to information on the range of values). Minimum and maximum values may be 'outliers' and not necessarily representative of the likely values of the ecosystem service.
3. **Confidence intervals**. A confidence interval is an estimated range of values which is likely to include the actual value. The estimated range is calculated from the set of sample data on the ecosystem service value under consideration. Confidence intervals are usually expressed as a range of values within which the actual value lies with a given confidence level or probability.
4. **Sensitivity analysis**. A sensitivity analysis can be used to show how estimated ecosystem service values change as value function parameters, data inputs and assumptions change. A sensitivity analysis involves systematically varying (within plausible ranges) the uncertain inputs to a model 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.

Given the current scientific understanding of seabed ecosystems, the services they provide and how these will be impacted by mining activities, it is unlikely that the value of impacts to ecosystem services will be estimated with high certainty. The question therefore becomes, how much uncertainty is too much? Assessments of the 'size' of uncertainty are important but require careful interpretation and are not comparable across contexts. Arguably the simplest and most general answer to this question is that the degree of uncertainty becomes unacceptable when a valuation estimate no longer provides information that enables better decisions to be made. For example, if the level of uncertainty is such that the analyst or decision maker can still tell whether, say, the ecosystem service benefits of a new MPA (with uncertainty) are clearly greater or less than the costs of the MPA (with uncertainty), then that information helps the decision, and the level of uncertainty is acceptable.

Different decision-making contexts may require different levels of certainty regarding the information that they use. For example, the use of value information for raising general awareness of the importance of ecosystem services arguably does not need to be as accurate as valuation information used in setting compensation of damages to ecosystems. A general ordering of decision contexts with respect to their required level of accuracy for value information is represented in Figure 8.

The level of uncertainty and the accuracy requirement of each decision-making context should be assessed to determine whether the estimated values can provide sufficiently accurate information. In the case that estimated values are judged to be insufficiently accurate, it is advisable to conduct robust valuations using more reliable methods, if resources (data, time, expertise, knowledge) are available.

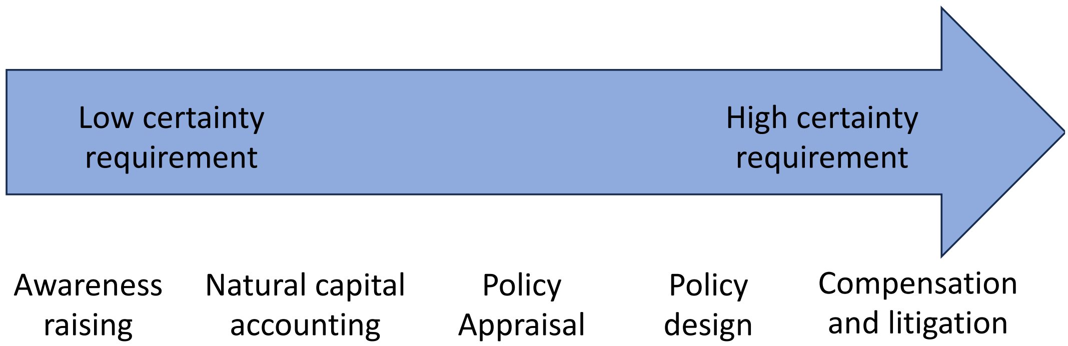

Figure 8. Certainty requirements for different applications of value information (adapted from Brouwer *et al.*, 2009).

5. Undertaking the valuation

Undertaking a valuation study can be viewed as comprising two phases: firstly preparing the valuation study; and secondly conducting the valuation study (see Figure 9). Preparing for a valuation of ecosystem services involves the following steps: 1. Defining mandate and demand for valuation; 2. Identifying which ecosystem services need to be valued and who the beneficiaries are; 3. Reviewing existing studies and data in order to build on the information that is already available; 4. Defining the objectives of the valuation study and selecting the appropriate methods; 5. Building a team that can complete the valuation and report the results. Depending on the selected methods, conducting the valuation involves: a. Data collection, surveying and sampling; b. Analysis of data to estimate ecosystem service values; c. Developing scenarios for future provision of ecosystem services. These steps are elaborated on in the following sections. Note that the ordering of some of these steps can be flexible. For example, the study preparation might start with a joint exercise of identifying the key ecosystem services and beneficiaries together with the identification of threats and what information is then needed as input to decision making.

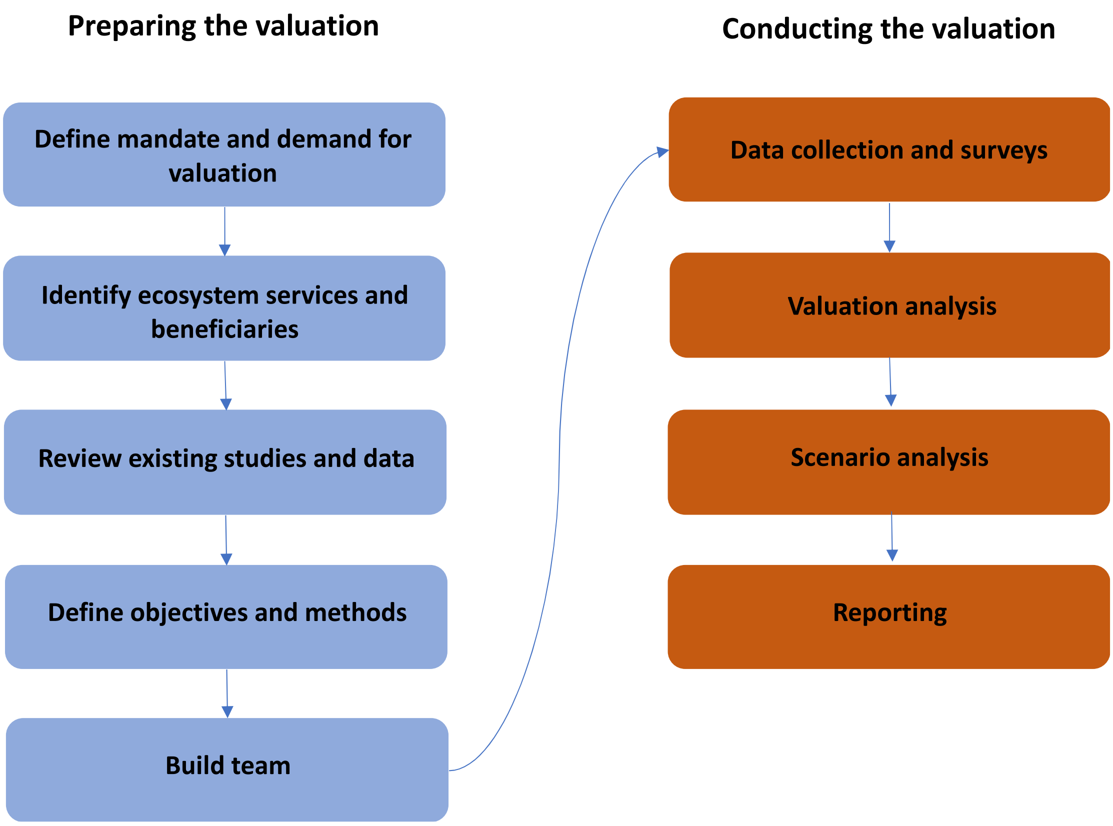

Figure 9. Steps in preparing and conducting a valuation study.

5.1 Define mandate and the demand for a valuation

The first step in preparing a valuation study is to identify the policy, management, or investment question the valuation is intended to address. What is the issue or challenge that needs to be addressed? What is the value information going to be used for? There are multiple possible uses and Section 3.3 provides a list of the main potential applications. In the context of deep-sea mining activities, the mandate for a valuation study on the external costs to ecosystem services is likely to be defined by the regulatory framework and the uses of the information could include the appraisal of mitigating activities or the setting of compensation payments.

Stakeholder engagement can play an important role throughout the valuation process, including identifying the questions that the study aims to answer, defining the scope, providing input to the valuation itself, and applying the results. For a valuation study to provide useful input to improve the management of marine ecosystems, it is essential that stakeholders are engaged. The valuation process itself offers the opportunity to raise awareness of environmental challenges, to get diverse stakeholders involved, to understand their concerns and address them, encourage ownership of the results, and ensure that results are subsequently used in decision-making.

A stakeholder is a person, group or organisation with direct or indirect interests in the impacted ecosystem that is the subject of the valuation. Potential stakeholders for a marine ecosystem may include, but not be limited to, marine industries and resource users; scientists/experts from different disciplines; government departments and agencies (e.g. environment, treasury, fisheries, protected areas) at multiple levels (communal, sub-national and national); non-governmental organisations; businesses; local communities; and the media. It is necessary to establish a balanced involvement of stakeholder groups to ensure representativeness and inclusivity.

The format of stakeholder engagement can take many forms including surveys, interviews, focus groups and workshops through which stakeholders can be asked to identify the key issues or threats facing marine ecosystems and the potential management or policy solutions. Participatory formats can be useful to allow discussion and reach consensus, but care needs to be taken regarding dominant relationships between stakeholders (e.g., resource owners and resource users) that might restrict the expression of different opinions.

5.2 Identify key ecosystem services and beneficiaries

The next step is to identify the key ecosystem services that are potentially impacted by mining activities and the relevant beneficiaries of those services. This can be based on the results of an Environmental Impact Assessment (EIA) where available. Identification of key ecosystem services is also often undertaken through stakeholder engagement. Again, this can take several forms including surveys, interviews, focus groups and workshops. One of the most effective ways to gather information on ecosystem services is through participatory mapping, in which workshop participants collectively discuss and describe the location of ecosystems and the services they derive from them. Participatory mapping or participatory GIS is a process in which multiple stakeholders (e.g. local community members, fishermen, business owners, scientists) jointly create an ecosystem services map, identify ‘hotspots’ of importance for ecosystem service supply and use. The process helps to integrate stakeholder perceptions and knowledge in maps of ecosystem services.

One potential challenge in obtaining information from local stakeholders on indigenous and traditional knowledge of ecosystem services is an observed reluctance to share such information. Such reluctance might be motivated by various factors including deference to formal scientific knowledge and experts, or unwillingness to speak in unfamiliar public settings. It is necessary to be aware of this challenge and design the engagement process to address it.

Another challenge in obtaining stakeholder input to identify ecosystem services is related to gender roles and participation. In many societies, men and women have different roles regarding natural resource and to some extent constitute different beneficiary groups. It can also be the case that women are not well represented in stakeholder engagement processes and so their use and dependence on ecosystem services is poorly identified. Again, it is necessary to be aware of this challenge and design the engagement process to address it.

5.3 Review of existing studies, information and data

Reviewing relevant valuation studies can provide guidance on applicable methods, identify gaps in existing knowledge, potentially be a useful source of data, and can also provide lessons in terms of challenges to address or avoid. There is a wealth of existing valuation studies on coastal and marine ecosystems, albeit relatively few for deep-sea ecosystems. The Ecosystem Services Valuation Database (ESVD) provides an open access platform for searching and summarising existing primary valuation studies.

5.4 Defining scope, objectives

Based on the preceding three steps, the scope of the valuation study can be defined in terms of geographic area, ecosystems, ecosystem services to be valued and their beneficiaries. The specific objectives should be defined in terms of type of value information that is required to answer the management/investment question. Ideally the key stakeholders should be consulted again to confirm that the scope and objectives meet their needs.

Regarding the geographic boundary of analysis, it is likely to extend beyond the specific ecosystems from which resources are extracted. Deep-sea mining activities potentially have impacts on other ecosystems, particularly the water column above the resource and over a wider spatial extent through plume effects (Drazen et al., 2020; Weaver and Billett, 2019). It is also possible that downstream processing activities located on land will have impacts on terrestrial and coastal ecosystems that should be considered as external costs. This can draw on the Environmental Impact Statement produced for the proposed activity.

5.5 Selecting valuation methods

The selection of relevant valuation methods is largely driven by the ecosystem services that are to be valued and the type of value information that is needed. Additional factors for consideration are the available resources for conducting the valuation and the availability of data since some methods have greater time and data requirements than others. Section 4 provides details on the applicability, requirements, strengths and weaknesses of available ecosystem valuation methods.

A tiered approach is proposed to provide a broad indication of which analytical approach is the best fit for a project context. Higher tier methods will provide more detailed and precise output, and typically require more input data, time, resources, and expertise to implement.

- Tier 1: Rapid assessment methods that rely on expert elicitation for scoping ecosystem services and impacts of mining activities; valuation of costs and benefits using existing data and unit value transfer.
- Tier 2: Methods largely rely on globally available geospatial/economic data but generate more precise quantitative and context specific results. For instance, through engaging stakeholders to scope relevant ecosystem services; quantifying biophysical impacts considering hazard, exposure, and vulnerability; and using value functions to adjust ecosystem service values to the local project context.
- Tier 3: Methods that require local data collection (e.g., interviews and field observations) and deliver greater accuracy. This includes participatory approaches for scoping ecosystem services and impacts; high-resolution impacts assessment using site specific data; valuation of ecosystem services using primary data (e.g., stated preference methods and relevant market prices).

5.6 Building a team with all required competencies

The mix of expertise within the research team conducting the valuation will depend on the ecosystems, services and methods that have been identified. In general, an ecosystem service valuation will involve an understanding of the bio-physical processes and functions of the ecosystem that underlie the delivery of services, the estimation of preferences and values received by beneficiaries, and knowledge of the management or policy process into which the value information feeds. The research team therefore needs to include expertise from bio-physical and social science disciplines. Often it is also useful to include GIS expertise for the purposes of obtaining and extracting spatial data, modelling ecosystem service flows, and mapping results to highlight their spatial distribution.

5.7 Data collection, survey and sampling methods

Data for valuation studies include multiple types including both secondary (existing data sets, maps and statistics) and primary data (collected first-hand for the purposes of the study).

Primary data for a valuation study can be collected in a number of ways including direct observations and measurements (e.g. fish catch, number of visitors), stakeholder interviews, participatory workshops, and surveys of beneficiaries.

Economic and social valuation methods often use surveys of beneficiaries to collect data on their perception, use and value of ecosystem services. A survey is a process of collecting information from a target population by recording answers to a set of questions (a questionnaire). Basic principles for developing a questionnaire include:

- Use simple language and avoid technical terms and jargon
- Use understandable and locally relevant units of measurement
- Use short questions and limit number of questions to avoid respondents losing attention and not completing the questionnaire
- Ask precise questions that obtain one piece of information at a time so that the interpretation of responses is clear
- Collect socio-economic and demographic information on the respondent in order to analyse the influence of such factors on responses
- Test the questionnaire for clarity of questions and answer options through focus groups or small samples and revise if necessary. The usefulness of testing the questionnaire cannot be over-emphasized.

Methods for conducting a survey include face-to-face interviews, telephone interviews, postal/mail delivery and return, and internet surveys. The costs and effectiveness of each method varies. In general, conducting face-to-face interviews is the most expensive approach but also observed to obtain more reliable responses. Internet surveys are low cost and can obtain large sample sizes but face difficulties in communicating complex information and questions. The combination of face-to-face interviews with web-based tools (online response forms administered using mobile devices) offer a promising approach.

Generally, it is not feasible or affordable to interview the entire target population of a survey and so it is necessary to collect information from a subset or sample of that population. Ideally the sample should be representative of the population so that the collected information can be interpreted as reflecting the values of the population. Representativeness of the sample should be monitored by comparing key characteristics (e.g. gender, age, income) of the sample and target population during the survey implementation. At this stage, if specific characteristics are under-represented, they can be targeted in subsequent sampling.

Two general approaches to identifying individuals or households to invite to answer a questionnaire are through random or convenience sampling. Random sampling selects members of the target population randomly but requires data or a list of the target population to select from, which is not always available. Convenience sampling involves selecting respondents that are easily accessible (e.g. on the street) but is likely to be biased towards certain types of people and non-representative of the target population.

5.8 Valuation analysis

The analysis of collected data to estimate economic values for ecosystem services encompasses a diverse range of statistical techniques depending on the valuation method that is employed. The technical complexity of each primary valuation is indicated in Table 3. The more technically complex methods generally involve the use of regression analysis to model marginal values for changes in ecosystem service provision. It is beyond the scope of this guidance document to describe method specific analytical steps in detail and we refer to the guidance material listed in Section 4.3.1.

5.9 Developing scenarios

Scenarios can be used to explore how ecosystem services might change in the future and how these changes can influence human well-being. Depending on the purpose of the ecosystem valuation, it is often useful to inform decision making by estimating the value of ecosystem services under a set of future scenarios representing alternative development paths or management options.

A scenario is a description of the future that might potentially arise under certain assumptions and conditions. Scenarios can be defined in terms of a set of key variables (e.g. ecosystem extent, condition, provision of services, number of beneficiaries etc.) and the values that these variables take over time. Note that a scenario does not only describe the state of an ecosystem for a single year in the future but for the entire time profile between the start (usually the current year) and end of the period of analysis. Scenarios should be plausible and internally consistent. The development of scenarios can use a number of different approaches:

- Predictive – predict what future ecosystem conditions, service provision and use will be under likely assumptions and driving factors.
- Explorative – describe future conditions etc. under possible assumptions and potential policy directions. Explorative scenarios ask "what if …."
- Back casting – identify desired future ecosystem conditions etc. and work backwards to describe courses of action that would achieve that future outcome.

The process of developing scenarios can usefully involve stakeholder consultation to obtain inputs on plausible futures and management options. Participatory scenario planning applies various tools and techniques (e.g. brainstorming or visioning exercises) to develop descriptions of alternative future options. Assumptions about future events or trends are questioned, and uncertainties are made explicit. Participatory scenario planning typically takes place in a workshop setting, where participants explore current trends, drivers of change and key uncertainties, and how these factors might interact to influence the future.

5.10 Reporting

Communicating the results of the ecosystem service valuation to the stakeholders that will use the information potentially requires different reporting formats and ways of presenting information, e.g. technical reports, policy briefs, films, social media coverage). The tools to communicate the main messages of the study can include statistics, indicators and visual representation (e.g. maps, illustrations, diagrams, pictures, charts, graphs, tables). It is generally useful to communicate results through multiple avenues. Technical reports are necessary to ensure that all sources and analyses are well documented but are generally not widely read. Annex

2 provide a general outline for an economic valuation report. Executive summaries, synthesis reports and policy briefs that distil the main results and message into one or two pages can be more accessible and effective in disseminating information. Other media, such as short videos or animations can also be more engaging for a wider audience. For such communication materials it is important to use suitable language and visual information, and to avoid using jargon or technical terminology.

6. Conclusion

The purpose of applying the valuation methods introduced in this guidance report is ultimately to provide relevant, credible and actionable information to support better use and management of resources in the Area. This primary aim should be kept firmly in mind when applying methods and presenting results; and any application should be designed to provide information that is directly useful and understandable to the decision makers involved. Adhering to the following conditions/principles can help ensure that the information produced by a valuation study achieves this aim: access to and partnership with the decision-makers using the information; identify clear policy/investment questions or information demands to be addressed; and high transparency regarding the methods, data and analysis to ensure trust and credibility. The valuation of ecosystems is not an end in itself, but a means to better informed decision-making that results in sustainable use of the marine environment.

7. Glossary of terms

Avoided (damage) cost valuation method: A cost-based valuation technique that estimates the value of the role an ecosystem plays in regulating natural hazards (e.g. flooding) by calculating the damage that is avoided due to the ecosystem service.

Choice modelling: Choice modelling attempts to model the decision process of an individual 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.

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.

Deliberative methods: An umbrella term for various tools and techniques engaging and empowering stakeholders in the valuation process. These methods ask stakeholders to share and form their preferences for ecosystem services in a transparent way through an open and structured discourse.

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: 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 bene t refers to a positive change in human well-being.

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 well-being.

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 well-being or utility 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 well-being (social welfare).

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 goods (e.g. fish, timber, water) and services (e.g. water filtration, coastal protection, recreational opportunities).

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 (*ex ante*) or after (*ex post*) 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.

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

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.

Hedonic pricing method: A revealed preference method for valuing environmental quality or resources that are attributes of a marketed good or service.

Indirect use value: The contribution of a resource to human welfare without direct contact between the beneficiaries and the resource. In general, indirect use values are obtained from regulating services such as carbon storage, coastal protection and flood regulation.

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: A lost in welfare of one economic agent caused (unintentionally) by the consumption or production behaviour of another economic agent. An example of a negative externality is the health impacts from air pollution caused by the use of petrol vehicles.

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.

Non-use value: The welfare 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 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 to represent economic value.

Purchasing power parity adjusted exchange rate: An exchange rate that equalizes 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.

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 (SCC): 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 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: All marketed and non-marketed benefits derived from a resource, including direct, indirect, option and non-use values.

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 well-being (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 these *Guidelines* 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.

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9. References

Brander, L.M. (2013). Guidance manual on value transfer methods for ecosystem services. United Nations Environment Programme (UNEP). http://wedocs.unep.org/handle/20.500.11822/8434

Brander L.M. (2018). Environmental Economics for Marine Ecosystem Management Toolkit. Global Environment Facility (GEF) LME:LEARN. https://iwlearn.net/manuals/environmental-economics-for-marine-ecosystem-management-toolkit.

Brander, L.M., van Beukering P., Balzan, M., Broekx, S., Liekens, I., Marta-Pedroso, C., Szkop, Z., Vause, J., Maes, J., Santos-Martin F. and Potschin-Young M. (2018). Report on *economic mapping and assessment methods for ecosystem services*. Deliverable D3.2 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007.

Brander, L.M. (2022). Guidelines on Methodologies for the Valuation of Coastal and Marine Ecosystems and their Application in the Western Indian Ocean. United Nations Environment Programme (UNEP).

Brander, L.M. and Guisado Goñi, V. (2023). The value of ecosystem services and natural capital of the Area. International Seabed Authority. https://www.isa.org.jm/wp-content/uploads/2023/06/Report-on-Valuation-of-ecosystem-services.pdf

Brander, L.M., de Groot, R., Schägner, P., Guisado-Goñi, V., van 't Hoff, V., Solomonides S., McVittie, A., Eppink, F., Sposato, M., Do, L., Ghermandi, A., Sinclair, M., Thomas, R. (2023). Economic values for ecosystem services: A global synthesis and way forward. Ecosystem Services.

Brouwer, Roy, David Barton, Ian Bateman, Luke Brander, Stavros Georgiou, Julia Martín-Ortega, Stale Navrud, Manuel Pulido-Velazquez, Marije Schaafsma, and Alfred Wagtendonk, 2009. "Economic valuation of environmental and resource costs and benefits in the water framework directive: technical guidelines for practitioners." Institute for Environmental Studies, VU University Amsterdam, the Netherlands.

De Groot, R., Fisher, B., Christie, M., Aronson, J., Braat, L., Gowdy, J., Haines-Young, R., Maltby, E., Neuville, A., Polasky, S. and Portela, R. 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In Kumar, P. (ed.) The economics of ecosystems and biodiversity: Ecological and economic foundations (pp. 9-40). Taylor and Francis.

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

Defra (2013). Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services. Department for Environment, Food & Rural Affairs. https://www.gov.uk/ecosystems-services

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... & Polasky, S. 2018. Assessing nature's contributions to people. Science, 359(6373), 270-272.

Drazen, J. C., Smith, C. R., Gjerde, K. M., Haddock, S. H., Carter, G. S., Choy, C. A., ... & Yamamoto, H. (2020). Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. Proceedings of the National Academy of Sciences, 117(30), 17455-17460.

Freeman, A.M.I. (2003). The Measurement of Environmental and Resource Values. Resources for the Future, Washington D.C.

GEF IW:LEARN (2018). Global Environment Facility (GEF) Guidance Documents to Economic Valuation of Ecosystem Services in International Waters Projects. https://www.iwlearn.net/resolveuid/0ffc8834-af39-488a-852a-4348fee97b85

GEF LME:LEARN (2018). Environmental Economics for Marine Ecosystem Management Toolkit. https://iwlearn.net/manuals/environmental-economics-for-marine-ecosystem-management-toolkit

Haines-Young, R. and Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, 1, 110-139.

Hensher, D. A., Rose, J. M., and Greene, W. H. (2015). *Applied choice analysis: a primer*. Cambridge University Press.

IPBES (2016). Guidance on Diverse Values and Valuation. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). https://www.ipbes.net/diverse-values-valuation

Johnston, R.J., Boyle, K.J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R. and Tourangeau, R. (2017). Contemporary guidance for stated preference studies. Journal of the Association of Environmental and Resource Economists, 4(2), 319-405.

Kahn and Greene (2013). Selecting discount rates for natural capital accounting, ONS-DEFRA.

Koetse, M. J., Brouwer, R., & Van Beukering, P. J. 2015. Economic valuation methods for ecosystem services. Ecosystem services: From concept to practice, 108-131.

MA (2005). Millennium Ecosystem Assessment: Ecosystems and human well-being. Island Press.

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

OECD (2018). Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris. https://www-oecd-org.vu-nl.idm.oclc.org/governance/cost-benefit-analysis-and-the-environment-9789264085169-en.htm

Pearce, D. W., and Turner, R. K. (1990). Economics of natural resources and the environment. Johns Hopkins University Press.

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

Pearce, D. (2003). Valuing the future: Recent advances in social discounting.

Pearce, D. (2003). The social cost of carbon and its policy implications. Oxford review of economic policy, 19(3), 362-384.

Rennert, K., Errickson, F., Prest, B.C., Rennels, L., Newell, R.G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B. and Smith, D. (2022). Comprehensive evidence implies a higher social cost of CO2. Nature, 610(7933), pp.687-692.

Salcone J., Brander, L.M. and Seidl, A. (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. http://macbio-pacific.info/Resources/marine-ecosystem-services-valuation-in-the-pacific/

Santos-Martín, F., Plieninger, T., Torralba, M., Fagerholm, N., Vejre, H., Luque, S., ... & Montes, C. (2018). Report on Social Mapping and Assessment methods Deliverable D3. 1EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007.

Schaafsma, M., Bartkowski, B., and Lienhoop, N. (2018). Guidance for Deliberative Monetary Valuation Studies. International Review of Environmental and Resource Economics, 12(2-3), 267-323.

TEEB (2021). Guidance manual for country studies. http://www.teebweb.org/resources/guidance-manual-for-teeb-country-studies/

Ten Kate, K., Bishop, J., & Bayon, R. (2004). Biodiversity offsets: Views, experience, and the business case. IUCN--The World Conservation Union.

Tol, R. S. (2023). Social cost of carbon estimates have increased over time. *Nature Climate Change*, 1-5.

UK Treasury (2018). The green book: Central government guidance on appraisal and evaluation. London: HM Treasury.

UNEP (2021). Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States.

https://www.cbd.int/financial/monterreytradetech/unep-valuation-sids.pdf

UNEP (2021). Guidance manual on value transfer methods for ecosystem services. http://wedocs.unep.org/handle/20.500.11822/8434

UNEP (2013). Guidance toolkit for the valuation of regulating services. http://www.ecosystemassessments.net/resources/guidance-manual-for-the-valuation-of-regulating-services.pdf

VALUES (2021). Methods for integrating ecosystem services into policy, planning, and practice. http://www.aboutvalues.net/about_values/

van Beukering, P., Brander, L., Tompkins, E., and Mackenzie, E. (2007). Valuing the environment in small islands: An environmental economics toolkit. Joint Nature Conservation Committee. http://jncc.defra.gov.uk/page-4065

van Zanten, B.T., Gutierrez Goizueta, G., Brander, L.M., Gonzalez Reguero, B., Griffin, R., Macleod, K.K., Alves Beloqui, A.I., Midgley, A., Herrera Garcia, L.D. and Jongman, B. (2023). Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO. https://naturebasedsolutions.org/knowledge-hub/58-assessing-benefits-and-costs-nature-based-solutions-climate-resilience-guideline

Vihervaara, P., Mononen, L., Nedkov S., Viinikka, A. (2018). Biophysical mapping and assessment methods for ecosystem services. Deliverable D3.3 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007.

Weaver, P. P., and Billett, D. (2019). Environmental impacts of nodule, crust and sulphide mining: an overview. Environmental issues of deep-sea mining: Impacts, consequences and policy perspectives, 27-62.

WRI (2012). Guidance toolkit on coastal capital. World Resources Institute. http://www.wri.org/our-work/project/coastal-capital-economic-valuation-coastal-ecosystems-caribbean.

10. Annex 1. Economic value

Economic value is a measure of the human welfare derived from the use or consumption of goods and services. Economic valuation is one way to quantify and communicate the importance of something (e.g. environmental damage, changes in resource availability, ecosystem services etc.) to decision makers, and can be used in combination with other forms of information (e.g. bio-physical indicators and social impacts). The comparative advantage of economic valuation is that it conveys the importance of environmental change directly in terms of human welfare and uses a common unit of account (i.e. money) so that values can be directly compared across other goods, services, investments and impacts in the economy.

Here definitions of the various concepts of economic value that are relevant to the assessment of coastal and marine ecosystems are provided.

In neo-classical welfare economics, the economic value of a good or service is the monetary measure of the well-being associated with its production and consumption. In a perfectly functioning market, the economic value of a good or service is determined by the demand for and supply of that good or service. Demand for a good or service is determined by the benefit, utility or welfare that consumers derive from it. Supply of a good or service is determined by the cost to producers of producing it. Figure A1 Panel 1 provides a simplified representation of demand (marginal benefit) and supply (marginal cost) for a good traded in a market at quantity ‘Q’ and price ‘P’.

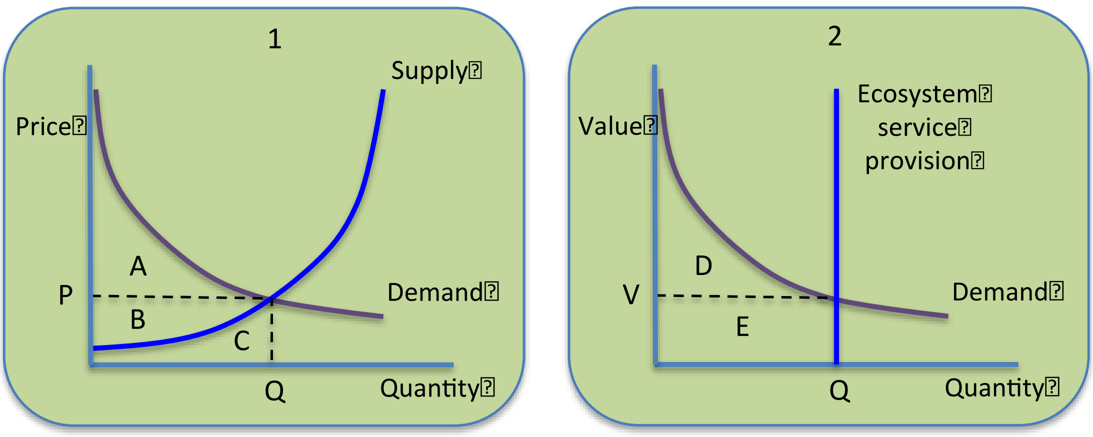

Figure A1. Demand and supply curves for marketed goods and services (Panel 1) and non-marketed goods and services (Panel 2) (see text for explanations of symbols). Source: Brander et al., 2018b.

In Figure A1 Panel 1, area ‘A’ represents the **consumer surplus**, which is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price that they would be willing to pay (which is related to their benefit from consumption and represented by the demand curve). The **producer surplus**, depicted by ‘B’, is the amount that producers benefit by selling at a market price that is higher than the lowest price that they would be willing to sell for (which is related to their production costs and represented by the supply curve). The area 'C' represents production costs, which differ among producers and/or over the scale of production. The sum of areas A and B is the total surplus in this market, and is interpreted as the net economic gain or welfare resulting from production and consumption with a quantity of Q at price P.

In the case that goods and services are not traded in a market (as is the case for many ecosystem services such as climate regulation, coastal protection and biodiversity), the interpretation of the welfare derived from their provision can also be represented in terms of surplus. Figure A1 Panel 2 represents the supply and demand of a non-marketed service. In this case, the 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. The quantity of the service that is 'supplied' is not determined through a market at all but by other decisions regarding protection status, land use, management, access etc. The quantity of the service supplied is therefore independent of its value. This is represented in Figure A1 Panel 2 as a vertical line. The demand curve for non-marketed services is still represented as a downward sloping line since marginal benefits are expected to decline with quantity (the more a service is available, the lower the additional welfare of consuming more). In this case, consumers don't pay a price for the quantity (Q) that is available to them, but they do receive a benefit or value (V) and the entire area under the demand curve (D+E) represents their consumer surplus. It is useful to keep this Figure in mind when considering the measurement of service supply from a coastal or marine ecosystem and the welfare people derive from it.

Note that the demand for goods and services that are used as inputs into the production of marketed goods and services (e.g. the habitat and nursery service provided to fisheries by mangroves and coastal wetlands are generally uncompensated inputs into fisheries production) is derived from the demand for the good or service that is finally consumed (e.g. fish).

The **marginal value** of a good or service is the contribution to well-being of one additional unit. It is equivalent to the price of the service in a perfectly functioning market (P in Figure A1). Small changes in ecosystem service provision should be valued using marginal values. The **average value** of a good or service can be calculated as its total value divided by the total quantity of the service provided and consumed. From Figure A1 Panel 2, average value can be calculated as (D+E)/Q. Average values may be useful for comparing the aggregate value of a good or service relative to the scale of provision (defined in terms of units of provision, area of ecosystem or number of beneficiaries).

Total Economic Value (TEV)

The concept of **Total Economic Value** (**TEV**) of an ecosystem is used to describe the comprehensive set of utilitarian values derived from that ecosystem. This concept is useful for identifying the different types of value that may be derived from an ecosystem. TEV comprises **use values** and **non-use values**. Use values are the benefits that are derived from some physical use of the resource. **Direct use values** may derive from on-site extraction of resources (e.g. fisheries) or non-consumptive activities (e.g.

recreation). **Indirect use values** are derived from off-site services that are related to the resource (e.g. climate regulation, coastal protection). **Option value** is the value that people place on maintaining the option to use an ecosystem resource in the future. Non-use values are derived from the knowledge that an ecosystem is maintained without regard to any current or future personal use. **Non-use values** may be related to altruism (maintaining an ecosystem for others), bequest (for future generations) and existence (preservation unrelated to any use) motivations. The constituent values of TEV are represented in Figure A2. It is important to understand that the "total" in Total Economic Value refers to the identification of all components of value rather than the sum of all value derived from a resource. TEV is a comprehensive measure, as opposed to a partial measure, of value. Accordingly, many estimates of TEV are for marginal changes in the provision of ecosystem services but "total" in the sense that they take a comprehensive view of sources of value.

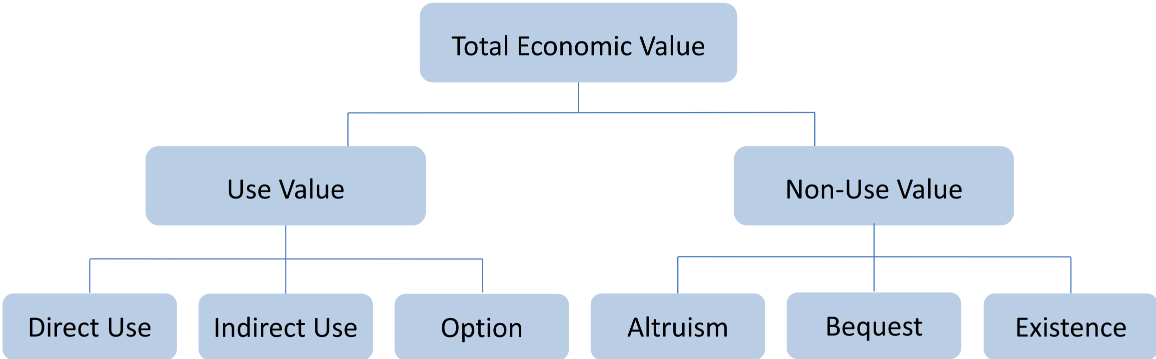

Figure A2. The components of Total Economic Value. Adapted from Pearce and Turner (1990).

The classification of different types of economic value within the concept of TEV is complementary to the classification of ecosystem services. Table A1 sets out the correspondence between categories of ecosystem service and components of TEV.

Table A1. Correspondence between ecosystem services and components of Total Economic Value.

	Total Economic Value			
Ecosystem service	Direct use examples	Indirect use examples	Option value	Non-use examples
Provisioning	E.g. fish		Option to use Provisioning service	
Regulation and maintenance		E.g. climate regulation	Option to use Regulating service	
Cultural	E.g. recreation		Option to use Cultural service	E.g. bequest value

Exchange value

The concept of welfare value is used in most assessments of ecosystem services, but it is not used in the System of National Accounts (SNA) that is used to calculate Gross Domestic Product (GDP) and other economic statistics. The SNA uses the concept exchange value, which is a measure of producer surplus plus the costs of production. In Figure A1 Panel 1 this is represented by areas B and C, or equivalent to P x Q. Under the concept of exchange value, the total outlays by consumers and the total revenue of the producers are equal. For national accounting purposes, this approach to valuation enables a consistent and convenient recording of transactions between economic units since the values for supply and use of products are the same. In the context of comparing the values of ecosystem services with values in the system of national accounts, it is therefore necessary to value the total quantity of ecosystem services at the market prices that would have occurred if the services had been freely traded and exchanged. In other words, it is necessary to measure exchange value and not welfare value.

The differences between the concepts of welfare value and exchange value are the inclusion of consumer surplus (A) in the former and the inclusion of production costs in the latter (C). The concept of welfare value corresponds to a theoretically valid measure of welfare in the sense that a change in value represents a change in welfare for the producers and/or consumers of the goods and services under consideration. The concept of exchange value does not correspond to a theoretically valid measure of welfare and a change in exchange value does not necessarily represent a change in welfare for either producers or consumers.[1]

[1] See Day (2013) for a more detailed explanation of welfare and exchange values.

11. Annex 2. Economic valuation report general outline

The contents of an economic valuation report will vary according to the policy/investment context but, in general, it will include the following sections:

1. Executive Summary
    - 1-2 page non-technical summary of the key results and conclusions of the study
2. Introduction - Background and Rationale of the Analysis
    - Description of the policy/investment context
    - Objectives and scope of the valuation study
    - Structure of the report
3. Conceptual framework for economic valuation of ecosystem services
    - Total Economic Value
    - Ecosystem services and natural capital
    - The case of economic valuation
4. Review of existing research
    - Brief review of relevant literature
    - Identification of knowledge gaps
5. Methods and data
    - Approach to stakeholder consultation/engagement
    - Identification of ecosystem services
    - Biophysical modelling of (impacts to) ecosystem services
    - Valuation methods and data collection
    - Scenario analysis
    - Sensitivity analysis
6. Results
    - Key ecosystem services
    - Economic value per ecosystem service
    - Scenario analysis
    - Sensitivity analysis
7. Discussion and conclusions
    - Summary of findings
    - Caveats, limitations and directions for further research
    - Policy/investment implications
8. References
9. Technical appendices
    - Survey development and instrument
    - Survey implementation and sampling
    - Full technical details of data, analysis and assumptions per valuation method