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Guide to Developing National Rapid Economic Assessments

of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species

Guide
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Building Partnerships to Assist Developing Countries to Minimize the Impacts from Aquatic Biofouling (GloFouling Partnerships) is a collaboration between the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the International Maritime Organization (IMO). The project aims to develop tools and solutions to help developing countries to reduce the transfer of aquatic invasive species through the implementation of the IMO Guidelines for the control and management of ships' biofouling.
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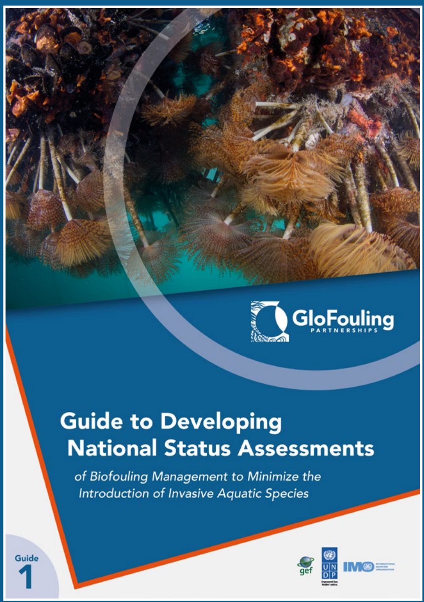
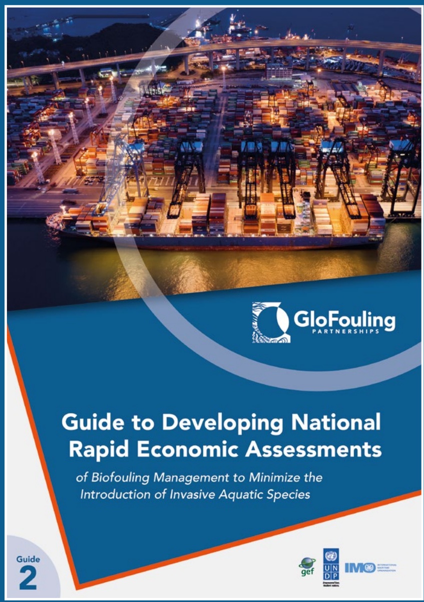
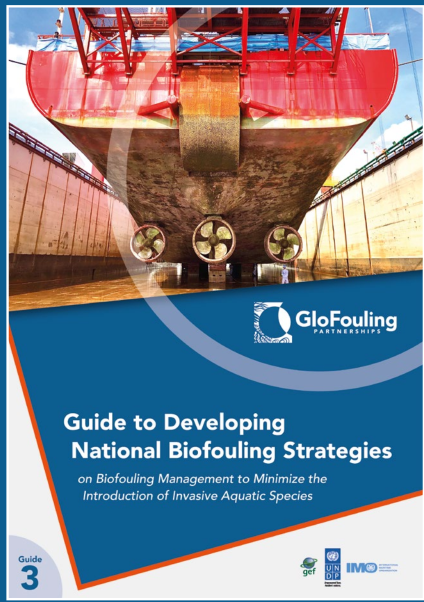
This Guide to Developing National Rapid Economic Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species (Guide 2) is the second out of a series of three guides, which were developed under the GEF-UNDP-IMO GloFouling Partnerships project. The three guides aim at assisting governments and interested stakeholders to minimize the risk of Invasive Aquatic Species (IAS) transferred through biofouling, by: conducting national status assessments to identify pathways, gaps and needs (Guide 1); assessing the economic costs and benefits of biofouling management to minimise the introduction of IAS (Guide 2); developing and adopting national biofouling strategies and action plans to minimize the introduction of IAS via biofouling (Guide 3).







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Acronyms and Abbreviations

AFS	Anti-Fouling systems
BFMP	Biofouling Management Plan
BFRB	Biofouling Record Book
CBA	Cost-benefit analysis
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CPI	Consumer Price Index
CSO	Civil Society Organization
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gases
GISP	Global Invasive Species Program
IAS	Invasive Aquatic Species
IMF	International Monetary Fund
IMO	International Maritime Organization
ISA	International Seabed Authority
LDCs	Least Developed Countries
MEPC	Marine Environment Protection Committee (IMO)
MW	Megawatt
NBMS	National Biofouling Management Strategy
NBS guide	Guide to Developing National Biofouling Strategies on Biofouling Management to Minimize the Introduction of Invasive Aquatic Species
NGO	Non-Governmental Organization
NIMS	Non-indigenous Marine Species
NPV	Net Present Value
NSA guide	Guide to Developing National Status Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species
NSA report	National Status Assessment report
PPP	Purchasing Power Parity
PSC	Port State Control
ROV	Remotely-operated vehicle
SEEMP	Ship energy efficiency management plan
SIDS	Small Island Developing States
TEEB	The Economics of Ecosystems and Biodiversity
TEU	Twenty-foot equivalent unit
TEV	Total Economic Value
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

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Foreword

Invasive Aquatic Species (IAS) are considered among the five greatest threats to the world's oceans and marine biodiversity (the other four being overexploitation of resources, pollution, habitat destruction and ocean acidification) (IPBES, 2019). Introduction of IAS can occur through many vectors and pathways, but biofouling of mobile marine structures such as ships and ship's ballast water are the two main acknowledged vectors (Ruiz et al., 2000; AMOG Consulting, 2002).

In the past, common belief concurred that ships' ballast water was primarily responsible for the introduction of IAS. However, recent research suggests that biofouling has been underestimated as a possible vector and may in fact represent the most common mechanism for the introduction of non-indigenous species. For example, some research estimates that up to 69% of introductions may have occurred via biofouling (Hewitt et al, 1999). Although some authors (Lovell et al, 2006) believe that this is poorly documented and difficult to quantify, the global impact of IAS transferred through this vector is likely to be significant.

Biofouling presents an opportunity for marine invasive species to hitch rides on the external part of marine mobile structures, such as ships, to new habitats outside from what would be considered their natural range. Nowadays, with the increased globalization and intensity of commerce, there are plenty opportunities for hitchhiking species. There are hundreds of thousands of ships, yachts, sailing boats, oil rigs and other floating structures in our oceans. What is worse, the ongoing sea temperature rise caused by climate change is allowing IAS to colonise ocean habitats that were once too cold to be hospitable.

Once introduced, IAS may disrupt fisheries, increase biofouling of coastal industry and infrastructure and interfere with human amenity. They damage their adopting habitat mainly by consuming native species, competing with them for food or space, or introducing disease.

Concern over and interest in biofouling also arises from practical considerations including the enormous costs resulting from biofouling of ships, nets, buoys, floats, pipes, cables and other underwater man-made structures. Specifically, the build-up of biofouling on ships poses a significant problem. In some instances, the hull structure and propulsion systems can be damaged. Additionally, the accumulation of biofouling species on hulls can increase both the hydrodynamic volume of a vessel and the hydrodynamic friction, leading to increased drag that can decrease speeds and require considerable increase in fuel consumption, while potentially overheating engines (by blocking intakes). Increased fuel use due to biofouling contributes to higher levels of greenhouse gas emissions from shipping.

The risk associated with biofouling may be unevenly distributed between different maritime sectors and between regions. For example, non-trading vessels such as offshore oil and gas infrastructure, fishing vessels, recreational craft or renewable energy structures may in some circumstances present a higher risk of IAS transfer through biofouling due to slower transit speeds, complex niche areas and greater periods of time spent in coastal waters, often stationary, where they are subject to biofouling recruitment.

The methodology proposed in this Guide will help determine, in a rapid and simplified manner, the potential economic impact of IAS to human activities and wellbeing and to the broader ecosystem services provided by our oceans. This will be compared to the cost of developing and implementing a national strategy and adopting best possible management measures to minimise biofouling across all industries. This is based on the understanding that preventing biofouling is possibly the most cost-efficient and effective option to reduce the risk of new IAS introductions out of the four typologies of interventions (prevention, eradication, containment and management).

Background

Purpose of Developing Economic Assessments

The implementation of a country-specific biofouling management framework aimed at minimising the introduction of IAS, will require countries to create their own policy defined by a national Biofouling Management Strategy and Action Plan that is consistent with the IMO Biofouling Guidelines. An essential part of the implementation of this national strategy and action plan is a detailed understanding of the costs and benefits of taking action to prevent future IAS.

The aim of this Guide is to help government agencies and departments working with issues related to biofouling and IAS, to assess and quantify the cost and benefits of developing and implementing a national policy for biofouling management to prevent potential consequences of unintended introductions of IAS. This analysis is intended to support sound decision making in relation to reducing risk related to IAS and as a source of information for the development and implementation of a National Biofouling Management Strategy (NBMS).

When considering options during the development of a NBMS, a simple economic assessment based on readily available data is often sufficient. While there are instances where a more detailed analysis may be desired, countries should take into account the complexity of the issue and the timescales required for further research.

The resulting national economic assessment report will help policy decision-makers to understand better the level of risk, the most suitable and cost-effective options and the budgetary requirements that would enable the implementation of a comprehensive biofouling management framework.

Purpose of this Guide

This Guide proposes a common and simplified methodology to be applied by all countries when developing a cost-benefit analysis of a national policy on biofouling management. The benefit of this approach is to obtain rapid estimations despite existing data and time constraints. It is also expected to facilitate standardization that may allow comparability between countries and/or industries.

The Guide is part of a three-book package that also includes:

- **Guide to Developing National Status Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species (NSA Guide)** – This publication helps to develop a baseline assessment on the status of a country in relation to the risk of IAS transfer through biofouling. The resulting NSA report will be an essential reference when considering the specific industries and ecosystems at risk from biofouling and/or IAS, the specific gaps identified in the country with regard to the implementation of a national policy for biofouling management and existing regulatory framework already available in the country in relation to biofouling and IAS. In this sense, the NSA report will be an invaluable source of information and references for the economic assessment.
- **Guide to Developing National Biofouling Strategies on Biofouling Management to Minimize the Introduction of Invasive Aquatic Species (NBS Guide)** – Aimed at helping countries to develop a national policy on biofouling management. The resulting national strategy will provide information on the main parameters to consider when estimating the cost of developing and implementing a national policy.

Structure of this Guide and how to use it

During the development of a national policy, the resources and timeframe available for conducting economic evaluation are typically limited. To overcome this constraint, the Guide includes a step-by-step process that will enable users to independently conduct a rapid and simplified economic valuation of relevant maritime industries and ocean ecosystem services using market price valuation and/or a customised case and value transfer approach. As far as possible, each step is accompanied by an illustrative example. Additionally, the Guide includes an outline for an economic valuation summary report (see Chapter 2).

The successful use of this publication does not require specialist knowledge of environmental economic approaches and methodologies. However, some understanding is required when assessing research available in each country and to understand the assumptions and uncertainties that may be involved. While detailed methods for economic assessment and valuation are beyond the scope of this publication, Chapter 1 and Annexes B and C include some information and suggestions that are useful when commissioning detailed studies.

This Guide is broken into four parts:

- **Chapter 1** covers the general approach to rapid economic assessment and cost benefit analysis. This includes information on challenges in relation to the valuation of ecosystem services, the main valuation tools available and their limitations, the specific methods used in this Guide and some of the key uncertainties and assumptions.
- **Chapter 2** outlines the key steps in the rapid analysis.
- **Chapters 3 and 4** provide detailed information on key data and parameters related to biofouling values that need to be assessed for maritime industries, other uses and non-uses, as well as how to cost the development and implementation of a national policy on biofouling management. Information in these sectors is commonly centred around estimating the cost of a new incursion of IAS (or the benefits of avoiding it). This information provides the foundation of estimating the benefits of a biofouling policy which contributes to reducing the scale of costs. Case studies and expert opinion are then needed to inform the degree to which those costs would be changed with a policy[1].

Annexes included in this Guide contain further reference and support materials that may be useful when using the calculation tool to develop an economic assessment. Specific mention to each annex will be made in the relevant areas of the Guide.

- **Annex A:** Ship fuel consumption and GHG emissions (Reference table that provides fuel consumption rates per ship category and size).
- **Annex B:** Valuation methods (An overview of the valuation methods that are commonly used for economic assessments).
- **Annex C:** Classification of marine ecosystem services.
- **Annex D:** Glossary of terms.
- **Annex E:** Other sources of information (Links to other resources and more information on environmental economic valuation initiatives).
- **Annex F:** Bibliography.

The Database of Case and Valuation Studies

To support calculations in relation to the methodology proposed in this Guide, a database has been created with a list of environmental economic valuation studies and a list of case studies on economic impacts of IAS. It is the result of an extensive search, screening hundreds of papers and selecting the few that are directly usable. It also includes materials compiled by the GEF Guidance Documents to Economic Valuation of Ecosystem Services in IW Projects (GEF IW:LEARN, 2019). The database is available online from the following link: https://docs.google.com/spreadsheets/d/10ACMgMz9u_VN-deS0gS7xz-gee-pQoCj3/edit?usp=sharing&ouid=117300532281063966085&rtpof=true&sd=true

[1] That is, case studies and or expert opinion would be used to estimate the percentage reduction in IAS costs that introducing a biofouling policy would achieve per species.

It contains information on studies considered directly usable for case transfers and value transfers, i.e. studies with values/benefit information that can be transferred to another area. It is the result of an extensive search, screening hundreds of research papers and valuation studies and selecting the few that are directly usable. The list is structured to easily identify the studies available for case and/or value transfers, to select the most appropriate ones, and to have all the information at hand to perform any adjustments to the values cited that might be necessary. Chapter 2 explains how to use the database. Practical examples are provided throughout Chapter 3.

1 General Considerations In Conducting a Rapid Economic Assessment

1.1 Setting The Scene

In the past, addressing environmental problems such as biofouling or Invasive Aquatic Species (IAS) has had a relatively low priority in policy circles. From an economic perspective, this is because the monetary value of managing the impacts of these problems has been poorly reflected in the market. Market prices rarely reflect well the costs arising from recognised impacts such as impeded vessel movement (which raises industry costs) or enabling IAS entry to a country (which can reduce the number of fish available to fishers over time or can harm biodiversity). And where the impacts of biofouling or IAS are poorly understood or are not recognised at all (say, in affecting culture or biodiversity), the costs of the problem may be entirely absent in the market.

This 'market failure' means that the cost to society of these types of environmental challenges has conventionally been poorly recognised during policy development. By comparison, the value of some forces that drive the problem (trade, for example) is relatively easier to discern. The result is that it can be hard for investments that control biofouling and IAS to compete on a level playing field with investments that drive the problem. Nevertheless, biofouling and IAS tangibly reduce human wellbeing. Omitting policies because biofouling and IAS costs are poorly valued in the marketplace means that human wellbeing will continue to be negatively affected across a range of industrial, social and cultural sectors.

To this end, explicit efforts to assess the economic value of environmental problems such as biofouling is increasingly recognised as an essential tool to inform policy. The underlying case is that valuation contributes towards more informed decision-making to ensure that policy appraisals take account of the effects of policy of human wellbeing. The ultimate aim of economic valuations is to offer insights for policy decision-makers by revealing how future policies could effectively deliver development priorities.

1.2 Determining the Value of Environmental Services: Key Issues and Trends in Relation to IAS

Research on the economic value of environmental services started in earnest in the 1960s in the face of increasing awareness among western countries of pollution (see Pearce 2002). In recent years, work on the economic value of environmental services has developed to improve understanding of the value of ecosystem services, including the value of biodiversity – and the effect of resource use choices on these values. This ecosystem service research – which forms the basis for appraising biofouling policies – has grown exponentially during the last 15 years, especially since the Millennium Ecosystem Assessment (2005). More recently, the TEEB Report ("The Economics of Ecosystems and Biodiversity"; De Groot et al. 2009), particularly the "TEEB for Water and Wetlands" (Russi et al. 2013), along with several international initiatives such as the UN's Intergovernmental Platform on Biodiversity and Ecosystem Services/IPBES, the EU's Common International Classification of Ecosystem Services/ CICES and the EU's Mapping and Assessment of Ecosystems and their Services (MAES), all of which are underlining the potential of the ecosystem services concept for sustainable policy and decision making. Additionally, research by UNDP (2017) shows that economic valuation of ecosystem services can effectively inform in-country decision-making in ways that support the transformation of how development is planned and acted upon towards sustainable solutions, depending on certain features of the valuation exercise.

However, methods and valid data to assess the provision of marine and coastal ecosystems (as needed for biofouling and IAS) and assess their monetary value are more limited than for the land-based environment. Furthermore, most valuation studies of marine ecosystems have focused on fisheries. A thorough review of global scientific literature confirmed that there were only 986 published papers

Box 1: What are Ecosystem Services?

Ecosystem services are the benefits people derive from nature. Human survival and well-being depend on these services and, therefore, on the conservation and sustainable management of ecosystems that provide the services. Ecosystem services are crucial for the well-being of people, but their contribution to economic systems is difficult to quantify in monetary terms. Since some of them are not quantified (i.e. not traded in commercial markets), they are often given too little or no weight at all in decision making (e.g. in the course of the development of big infrastructure projects). Thus, final decisions may favour outcomes which do have a commercial value, turning unsustainable use of ecosystems more profitable in a short term while having potentially considerable economic long-term costs.

on marine and coastal ecosystem services, of which only 145 included a quantitative synthesis (Liquete et al, 2013). The trend seems to have changed in recent years, with approximately 400 studies on coastal and marine ecosystem services published every year (Rodrigues et al, 2017).

When it comes to IAS, numbers are even lower. Despite growing recognition of the importance of the economic and ecological harm caused by IAS, linkages between invasions, changes in ecosystem functioning, and in turn, provisioning of ecosystem services, remain poorly documented and understood. Impacts of biofouling and IAS are volatile, uncertain, complex, or ambiguous.

The economic impacts of IAS are a result of their interference with biological resources that support fishing and coastal aquaculture (e.g. collapse of fish stocks), interference with fisheries (e.g. fouling of gears), disruption to tourism, damage to infrastructure (e.g. through fouling) and costs of treatment, clean-up or control. All these types of impacts are interconnected, tending to influence and exacerbate one another.

Until recently, approaches to assess IAS were commonly approached from a biological perspective and did not include economic assessments. When included, the economic assessments commonly centred on theoretical considerations with relatively little quantification. In other cases, no systematic empirical methods for estimating costs were used and monetary valuations were often presented without references or without an explanation of the methodology that was applied. This makes it very difficult to assess the validity of many assessments.

1.3 The Concept of Total Economic Value

A policy focusing on biofouling management and prevention of IAS transfers will change the values (e.g., costs) that those two issues impose on society. Assessing the potential value of such a policy means first identifying what those values are. Otherwise, it is not possible to choose the most appropriate valuation method to assess them from the range available to capture these values. (see Section 1.4)

The concept of Total Economic Value provides a framework to identify the values potentially affected by indicating the range of 'use' and 'non-use values' that ecosystems such as in the marine environment may provide (**Figure 1**, page 14). Identifying the different values is important to determine the valuation methods required to quantify the values.

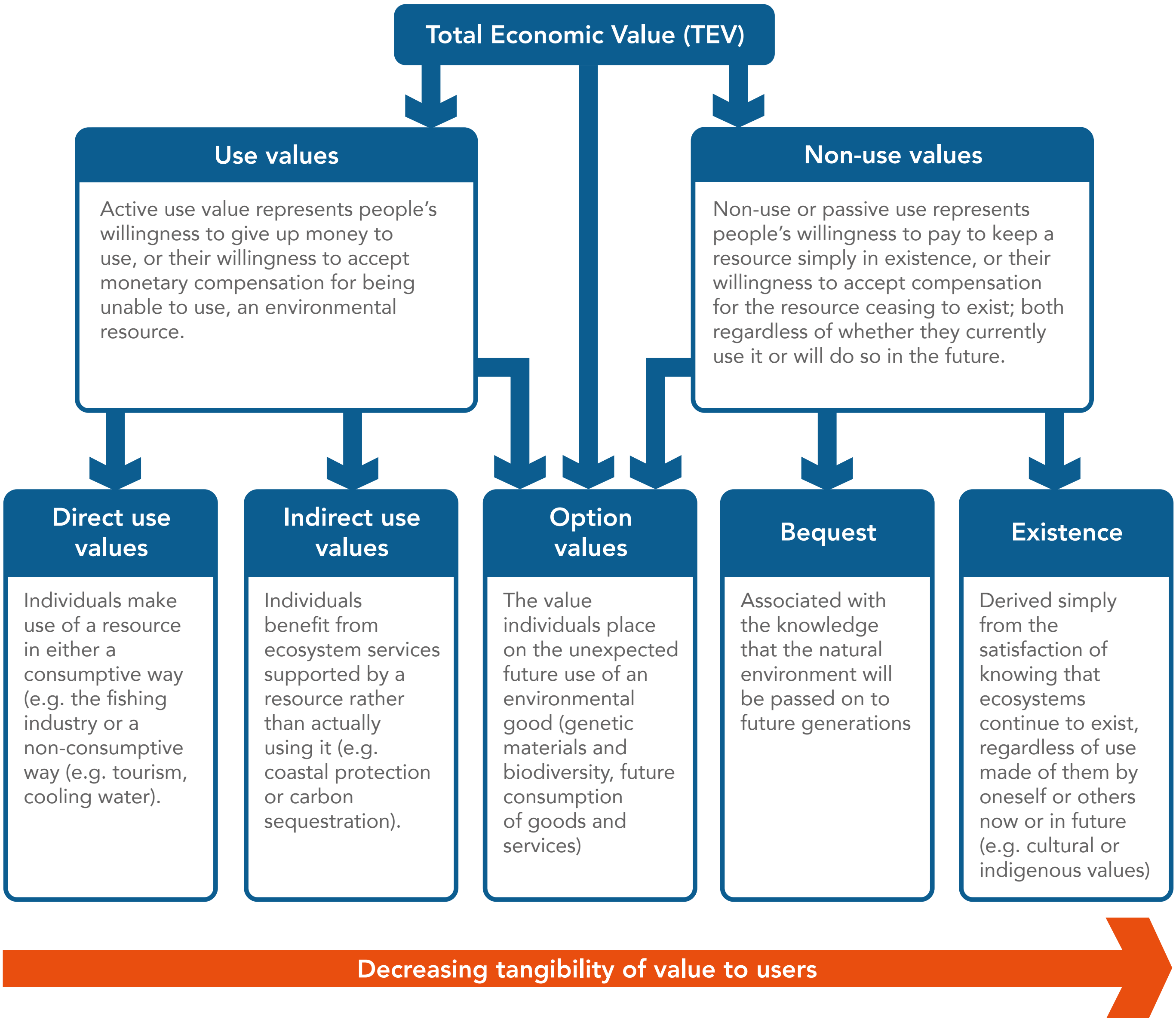


Figure 1: Total Economic Value

1.4 Valuation Methods and when to use them

A variety of methods exist to estimate the economic value of ecosystem services. A list of valuation methods can be found in Annex B but, generally speaking, these fall into the category of:

- 'revealed preference methods,' which estimate the value that consumers hold for an environmental goods or services by observing their purchase of goods or services in the market that directly (or indirectly) relate to environmental quality. These methods typically rely on secondary data to reveal values, although some primary data may also be applied. Or
- 'expressed preference methods' which measure the value of environmental goods or services by examining the expressed preference by individuals for them, relative to their demand for other goods and services. These methods typically rely on primary data for valuation, commonly collected through surveys.
- Additionally, some valuations may be attempted using information from previous assessments and applying it to new contexts. This is generally referred to as 'value transfer method.'

In the past when valuation of marine ecosystems has been attempted, the choice of valuation methods has been highly varied, with some publications using market-based methods ('revealed preference' methods) and others preferring to use survey-based approaches ('expressed preference' methods - i.e. people's value). More frequently, the estimation of ecosystem services in the past has been limited to direct use values such as food provisioning services, or recreation and tourism, without attempting to estimate the importance of indirect and non-use values. The result is that it has been difficult to compare values across studies as the scope of valuation has been so different,

Another valuation issue when considering policies is poor understanding of some ecosystem services provided by oceans and coastal habitats. While common classification systems of ecosystem services are provided by CICES, TEEB and the Millennium Ecosystem Assessment, Annex C presents an adaptation to marine services developed by the EU Vectors Project and by Liquete (Liquete et al, 2013). Analysts should familiarise themselves with the descriptions of the different types of services before attempting to identify potential impacts covered in Chapter 3. Ecosystem interdependencies and cascading impacts are poorly suited to analysis by economic methods that are based on marginal value concepts (Cicchetti & Wild, 1992). However, some indication of the trade-offs involved in marine management is better than none. The rapid economic assessment should be transparent about the limitations of ecosystem services values.

Economic evaluations using primary valuation methods can be resource-intensive, as a full analysis requires expert knowledge, large amounts of data, and are often time consuming and expensive. For information purposes, Annex B provides an overview of valuation methods, typical applications, limitations and indicates which valuation methods are indicated to value different types of ecosystem services. It is recommended that the reader is familiarised with some of these methods to assess the level of uncertainty of estimations found in existing research before using them for a value transfer.

For cases where knowledge and resources are limited, the "value transfer" method (also known as Benefit transfer) can be used to estimate economic values for ecosystem services that cannot be valued otherwise, by transferring available information from detailed original studies already completed in another location and/ or context. Value transfer is used when it is too resource intensive (in terms of money and expertise) and/or there is too little time available to conduct an original valuation study, yet some quantification of benefits is needed. Economic valuation using the value transfer methodology will generate values that provide a rough overview of potential values of ecosystem services in a specific case or context. The resulting figures can be used for communication and awareness raising purposes but should be handled with care and transparency when introduced into decision making processes.

This Guide will focus on using primarily two valuation methods: Market-based pricing and Value transfer (based on published case studies).

The Market Price Method

The market price method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. This method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods or services, based on the quantity people or companies purchase or use at different prices, and the quantity supplied at different prices.

The advantage is that for established markets such as maritime and coastal industries, data on costs, price, and volume are relatively easy to obtain. For this reason, the evaluation of impacts of biofouling and/or IAS on maritime industries should primarily use (where possible) data available in the country or area of study. If necessary, when data may be limited, extrapolation could be considered based on the information secured from a single production unit.

Box 2: Key limitations of the market price method

- Most ecosystem services are not traded in markets, making necessary other valuation methods.
- Market prices do not always deduct the market value of other resources used to bring ecosystem products to market, and thus may overstate benefits.
- Measuring the value of larger scale changes that are likely to affect the supply of or demand for a good or service.

Where possible, market imperfections and/or policy failures should also be taken into account, as they may distort market prices making them fail to reflect the true economic value of commodities to society as a whole. Common examples of market imperfections could be the existence of monopolies or state subsidies for power generation, aquaculture or fishing. Seasonal variations and other effects on price must also be considered.

The Value Transfer Method

New 'primary' valuation research, however, is generally time consuming and expensive. But decision-making often requires information at short notice and at low cost (i.e. limited budget to conduct research). For this reason, there are advantages in drawing on information from previous valuation studies to inform decisions regarding similar impacts on ecosystems that are of current interest. This transfer of value information from one context to another is called value transfer. Value transfer methods have been employed widely in national and global ecosystem assessments, value mapping applications and policy appraisals.

Value transfer is the use of research results from existing primary studies at one or more sites or policy contexts ("study sites") to predict estimates for other sites or policy contexts ("policy sites"). Value transfer in environmental valuation circles is more commonly referred to as the benefits transfer method. However, since the values that are transferred in this Guide 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.

1.5 Dealing with Unpredictability

There are considerable challenges that are common in relation to economic valuations of ecosystem services. These are not only linked to a lack of data and information, methodological issues surrounding assumptions and constraints, but also to a general lack of understanding of the complex interactions between human activities, impacts on ecosystems and habitats, and their ramifications for the provision of ecosystem services (see, for example, **Box 3**, page 20). It is evident that in almost all cases the value of ecosystem services will not be estimated with complete confidence. The resulting unpredictability – or the opaque communication of this – can hinder the uptake and use of economic valuation studies in policy making and as decision support.

Classification of Sources of Unpredictability

There are four situational characteristics that make management impact unpredictable. these are volatility, uncertainty, complexity, and ambiguity. Together the VUCA (Volatility, Uncertainty, Complexity and Ambiguity) framework (Bennett and Lemoine, 2014) provides a nuanced way to understand unpredictable impacts.

Volatility

A volatile environment is one where change is frequent and unpredictable, but information is available and understandable. IAS incursions are an example of volatility because the likelihood of an invasion by a particular species can be estimated, but not when it will happen. Invasions are unpredictable but are more likely to be detected when they do happen. Planning for volatility requires having a management plan that is flexible to new information and has enough slack resource to respond. Such a flexible management approach is likely to have economic value greater than might be suggested by a cost-benefit analysis (CBA). In other words, a CBA may underestimate the payoff of a flexible biofouling policy unless the option value associated with flexibility is explicitly included.

Uncertainty

Uncertainty occurs when there is insufficient information to know if there will be a significant impact. Addressing uncertainty requires the collection of more information, which could be challenging for a rapid economic assessment. **Table 1** (see next page) in the Guide highlights that sector-wide and environmental impacts are often very uncertain. Further in this section, some guidance is provided on how to register and describe data uncertainties.

Complexity

A complex situation is characterised by many interconnected parts, making it difficult to disentangle the impact of any single management action. Complexity is a problem when trying to assess the impact of a single management approach when other complementary policies may exist. Complexity can be addressed by focussing on a specific part of the problem. When assessing a biofouling policy, focussing on a preventative approach may reduce the unpredictability arising from complexity. However, if analysts then want to assess another management option (e.g., eradication), a separate assessment could lead to double-counting of benefits or costs. Complexity is also a problem in the assessment of ecosystem services benefits. A rapid economic assessment should acknowledge the existence of complementary policies and consider the potential for double-counting or synergies.

Ambiguity

Ambiguity occurs when there is doubt about the nature of cause-and-effect relationships. Under conditions of uncertainty, information exists but is not available to the decision-maker. Under conditions of ambiguity, the information does not exist because the situation has not yet occurred. The impact of a new pest on specific sectors or values might be ambiguous if those sectors have never experienced the pest before at all, or at a specific site where impacts may be particular. Similarly, the efficacy of management policy for a new pest might be ambiguous if the management option has not been tested on that species. Ambiguity can only be reduced through experimentation, which highlights the value of case studies about management policy. Unfortunately, there is no way to address ambiguity in an economic assessment, except to note that in the report (see Step 7) that some impacts may be unknown.

Managing Unpredictability

In view of the span of unpredictability facing policy makers concerned with biofouling, key questions will become: how much unpredictability is too much to ensure an effective policy? What level of unpredictability in an ecosystem is unacceptable (risking that the policy will fail)? And is it possible to improve on the rapid evaluation by collecting more information?

If ambiguity is the main source of unpredictability, then the answer to these questions is, unfortunately, no. Remaining questions about the extent, type and management of unpredictability are important but require careful interpretation and are not comparable across contexts. The simplest and most general answer to the question of acceptability is that the degree of unpredictability becomes unacceptable when a valuation estimate no longer provides information that enables better decisions to be made. For example, if the level of unpredictability is such that the analyst or decision maker can still tell whether benefits are clearly larger or smaller than costs, then that information helps the decision and the level of unpredictability 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 litigation for compensation of damages to ecosystems.

For the purpose of developing a rapid economic assessment in relation to biofouling and IAS, there are some specific uncertainties and assumptions that need to be considered when assessing values. **Table 1** below highlights the most common uncertainties that need to be taken into account by the reader. **Table 1** also includes an explanation of their potential impact on the assessment and the solution implemented in the methodology proposed by this Guide.

Table 1: Key uncertainties and assumptions

Challenges related to biofouling management		
Information needs	**Uncertainty**	**Solution/Assumption proposed in this Guide**
What is the best approach to IAS in relation to biofouling: preventing invasions; eradication; or living with the invasion	Estimating the cost of all policy options can result in increasing the complexity of an already difficult calculation, that would require overly dedication of time and resources and, due to the very high level of uncertainty, may provide a broad range of figures.	**This methodology is solely focused on estimating the cost of a preventive approach** to reduce the level or risk in relation to IAS. This is in line with the approach recommended by the IMO Biofouling Guidelines and is based on the consideration of biofouling as a key vector for the introduction of non-indigenous species that could potentially become invasive. Thus, **minimizing levels of biofouling across all maritime industries,** regardless of the species, would be conductive to a reduced risk of introductions.

Table 1: Key uncertainties and assumptions - continued

Challenges related to biofouling management		
Information needs	**Uncertainty**	**Solution/Assumption proposed in this Guide**
Assessing the economic and environmental benefits of energy efficiencies related to biofouling management across a fleet of ships with different hull shapes and operational profiles	The economic benefits of increased energy efficiencies derived by reduced drag of ships after implementing improved biofouling management practices will be variable. Some solutions have been recently developed to estimate the fuel consumption of ships and the impact of different biofouling management strategies. However, they all entail entering data for each individual ship. Considering the existing number of ships, types, hull designs and operational profiles, this solution is impractical due to the amount of time required and the unavailability of data.	Section 3.1 of the Guide proposes three different methods for a fast estimation of the fuel efficiencies derived from improved biofouling management across all ships registered under a flag State.
What is the prevalence of biofouling accumulation across the fleet and how to determine the number of ships under each level of biofouling	While it is difficult to estimate with certainty, data accumulated by researchers and in-water cleaning providers, points out that the uptake of efficient coatings and optimal biofouling management practices is mainly limited to a small proportion of internationally operating commercial ships. On the other hand, in sectors such as fishing, or coastal domestic shipping, light macrofouling seems to be prevalent.	**To estimate the cost of not managing befouling (or substandard biofouling management practices), this Guide will apply a fuel penalty of 20% to all ships.** This is equivalent in most cases to slime or light macrofouling, which would compensate for the section of the global fleet currently minimising effectively their levels of biofouling.
Challenges related to IAS		
Information needs	**Uncertainty**	**Solution/Assumption proposed in this Guide**
Assigning the value of economic impacts to the right vector (biofouling, ballast water, aquaculture, etc.)	It can be a difficult task to differentiate due to the shared role of all vectors. For example, an IAS may be introduced to an area through ballast water or aquaculture (or as a result of a combination of multiple vectors), and then expanded throughout the region by biofouling (also potentially in combination with other vectors).	This methodology will assume that, **despite the vector responsible for a primary introduction, if biofouling plays a role in secondary expansion, it will justify assigning to the biofouling vector the potential costs or benefits attributable to a specific IAS.**
Absence of national (local) studies on IAS, their impact, or the value of ecosystem services they may affect.	Inability to quantify the potential impact of IAS introductions to maritime industries or ecosystem services, particularly for non-use values.	The use of Case and Value transfers can be applied. This valuation method entails identifying case studies on IAS or ecosystem services in other regions with similar environmental conditions and assessing their application to another country.

Box 3: Examples of unpredictability and the challenges they generate

Areas of unpredictability that are common to economic valuations include:

- Complexity:
  - How different ecosystem services are interlinked with each other and to the various components of ecosystem functioning (and to which degree).
  - The methodological issue of "double counting", i.e. the fact that some ecosystem services are not complementary or influence each other (e.g. provision of fish/fisheries and spawning grounds, two values that should not be added).
- Uncertainty (information is unavailable):
  - When assessing the value of ecosystem services using the market price approach, it is often difficult to deduct the costs from the value (e.g. economic data for the fishing industry is typically provided as volume of catches or their market value – without providing information of the net profit). While on the national scale this may be still a good indicator, it is more difficult when countries or regions need to be compared.
  - Using expressed preference methods, such as the Contingent Valuation method, it is assumed that the expressed preference is similar to the revealed preference (i.e. such studies assume that questioned people would in reality pay the same amount of money for the assessed ecosystem services that they stated in the study, confronted by interviewer and/or questionnaire).
- Ambiguity (information does not exist). The simplifying assumption that the economic value of ecosystem services provided by one hectare of a certain ecosystem equals the value of ecosystem services provided by one hectare of the same ecosystem somewhere else (internationally when using a value transfer, but also within the same region). The point is that all hectares of an ecosystem do not have the same productivity, which means that increasing the size of e.g. a protected area by the factor 10 does not mean that the value of the ecosystem services provided also increase by the same factor.

Reporting Assumptions and Potential Sources of Error

When conducting an economic valuation, it is important to describe any volatilities, uncertainties, complexities or ambiguities that have been identified and to communicate any assumptions taken. This will enable reviewers to better understand how robust the policy is likely to be. The VUCA categories provide insights about whether it is possible to reduce information gaps. This aspect is particularly important when considering data on indirect impacts. To collected data in an orderly manner, a table such as the example in **Table 2** below, should be inserted in the final version of the economic assessment report as an appendix or annex. Key uncertainties with a major impact in the outcome of the calculations, should be highlighted and explained briefly in the summary of the report (refer further in the section). Examples of major uncertainties that need to be noted include the use of expert opinion or the use of transfer values from other case studies.

Table 2: Reporting uncertainties

Data description or aspect	VUCA category	Identified uncertainty or assumption made during the calculation	Relative importance (1, 2, 3, 4 – with 1 being the highest)

Assessing Assumptions with Exposure and Risk

Determining the potential economic impact of an invasion that has not previously taken place is a key element to estimating the effect on resources at risk. In the absence of local data, the potential impact of an invasion that may occur in a specific region or habitat can be estimated using transfer values based on case study impacts from a similar region. As explained in section 1.4, transfer values should be used with caution, by only using cases that include some common characteristics to the country or area to which they are being applied, amended to reflect local context or are supported by local or regional research. (This is discussed in more detail in Step 4 (Case transfers).

Nevertheless, this estimated value represents a potential invasion that has not taken place – and may not necessarily happen. In these extreme cases with a high level of uncertainty, it is important to ensure that this kind of estimations do not have an unjustified weight in the overall economic assessment. This is particularly important when assessing the potential impact of IAS on non-use values.

The approach taken in some cases is to estimate the probability of an incursion based on the rate of arrivals of non-indigenous species detected in the region. Several studies in Australia have attempted to estimate the incursion rates of IAS transferred through biofouling and ballast water (Cohen and Carlton, 1998; Hewitt, 2011; Arthur et al, 2015). Hewitt went even further to estimate that between 3.4 and 4.1 establishments of non-indigenous species per year could be attributed to biofouling. As not all non-indigenous species have major impacts (or become invasive), Hewitt compared this with a list of Species of Concern that had been identified by Australia as being of high risk and the estimated pool of non-indigenous species identified in the world but not present in Australia. With this data, the probability of arrival of an IAS through biofouling was estimated to be between 0.15 and 0.25 per year. It should be noted that the methodology used by Hewitt could have been influenced by changes in surveillance effort through the years, which would entail some overestimation of the rates of incursion (Lewis, 2011). However, it could be argued that this may be counterbalanced by the ever-increasing rate of marine traffic happening every year. Supporting this argument, another study (Sardain et al, 2019) predicts a dramatic, global increase in invasion risk by 2050, and suggests that this increase will primarily be due to estimated growth of shipping traffic, with environmental change having a marginal effect on invasion risk. This calculation proved true whether or not future environmental distances were calculated with respect to a source port's current or future environmental conditions. The resulting mean expected number of annual invasions showed to be between 3.91 and 23.40.

Other methods commonly used to determine risk levels are based on the number of ship arrivals in a country (or a port, for that case). However, these are mostly suited to the case of introductions via ships' ballast water, and would not take into account the increased traffic related to other maritime industries that can also act as pathways for the introduction of non-indigenous species and IAS, nor represents the higher levels of risk related to slow moving structures such as MODUs that have a much lower traffic frequency.

Where data to use these solutions is lacking, this Guide proposes the use of an illustrative incursion rate, as noted in **Box 4** (see next page). As suggested in Chapter 1.5 and **Table 3** (see page 26), the use of this (and other) assumption should be noted in the report of the assessment so that policy makers can understand the robustness of the estimate.

Box 4: Compensating assumptions with an invasion rate

The lack of information and research about the impact of IAS is one of the main problems when attempting to make rough estimations about their economic cost. Reports focusing on economic aspects are few, so in many cases, the only solution would be, where possible, the use Case transfers.

However, when using case transfers for a country or region where no similar case has been detected, represents a high-risk assumption that could have an excessive weight in the overall economic estimation. Linking the value to the likelihood of an invasion taking hold in the area of study would be the most suitable way to ensure that estimations made with a very high level of uncertainty, do not have an undue weight on the outcome of the assessment.

In the absence of studies that estimate the incursion rates of IAS in the country or region under assessment, this Guide proposes the use of the rate estimated by Hewitt et al., which is equivalent to an incursion rate in the absence of increased prevention measures of 0.25. While this estimation was based on an assessment made for Australia, where the level of biosecurity may be higher than in most other regions in the world, this rate could nevertheless be applied to other regions with similar levels of maritime activity and exposure.

Applying the Incursion rate to the values estimated in the assessment would be as follows:

Impact of IAS = Ce x IR

Where

Ce is the estimated impact of IAS on ecosystem services at risk

IR is the invasion rate in the absence of prevention (as per the paragraphs above, estimated at 0.25)

Practical examples on the application of this Incursion rate to estimations based on Case transfers can be found in Chapters 3 and 4.

2 Steps in a Rapid Economic Assessment

This Guide proposes a simplified methodology where it is not necessary to calculate the full TEV to quantify the economic impact of invasive species and biofouling. In fact, due to the high level of uncertainty that underlines any biological process, calculating the full TEV would be difficult to achieve due to the considerable data requirements, number of estimations and the likely need for the whole range of valuation methods. The outcome would be difficult to verify (particularly due to market behaviour), and such a large abstract figure that it would be almost irrelevant (e.g. see Constanza, 2014).

The methodology proposed in this publication is focused on identifying and assessing priority values related to the implementation of a biofouling policy, using a with and without framework (discussed in more detail in Step 3). Based on this, the key components on the methodology are the estimation of the costs from biofouling/ IAS (with and without a policy) and the estimation of policy execution costs, as shown in **Figure 2** below.

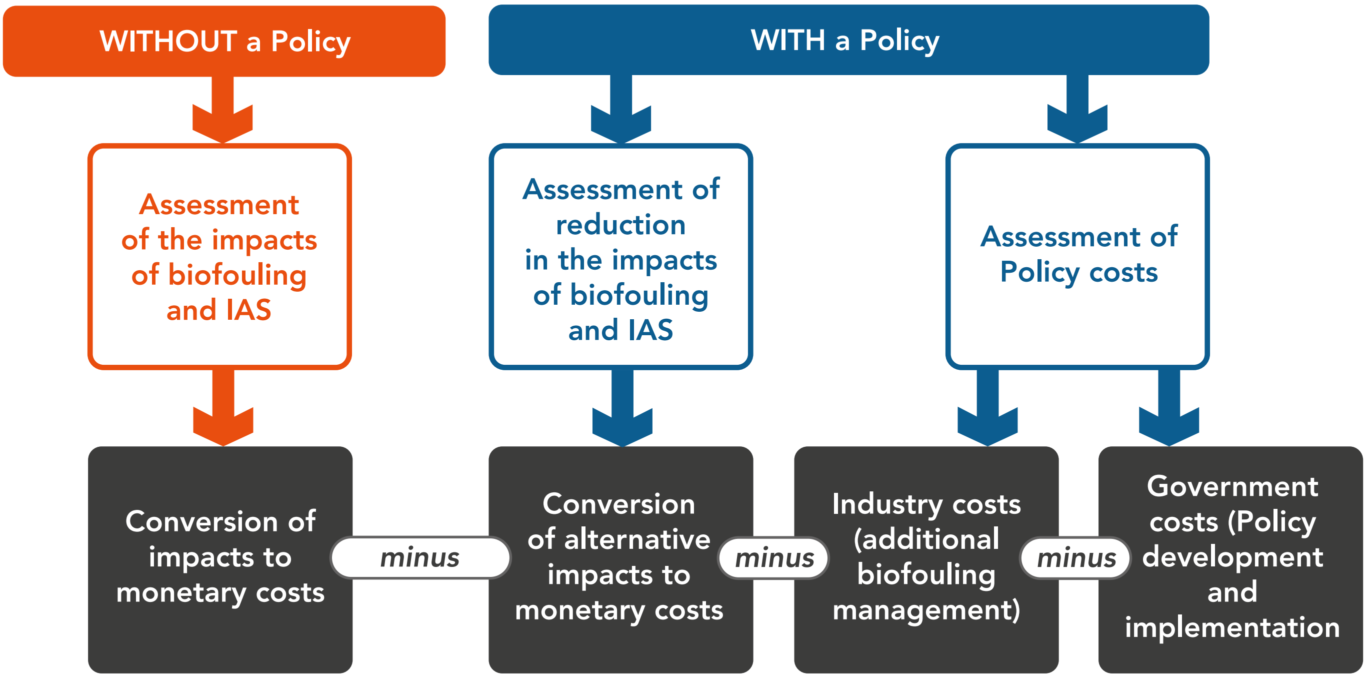


Figure 2: The methodology integrating ecosystem services and the TEV concept

The resulting report will determine an approximate value for the following parameters:

Economic impact of biofouling and IAS with and without a policy

- Impact of biofouling. This entails estimating the monetary value of potential production losses and/or increased expenditure, both for the maritime industries and for other ecosystem services contributing to the wider economy (with particular attention to use values) that could be attributed to biofouling if it were not prevented or managed.
- Impact of IAS. This entails estimating the monetary value of existing or potential production losses and/or increased expenditure attributable to IAS – in addition to the estimation for biofouling. The estimation should be made at the industry level and in other ecosystem services supporting the wider economy (with particular attention to non-use values).
- Benefits derived from IAS or biofouling. The existing or potential positive economic impacts rendered by IAS (for example value of sales for an invasive species that has entered the local food chain) and the benefits derived from new services related to biofouling.

Cost of a policy

- Management costs. The additional cost resulting from improved management

and monitoring biofouling in all maritime industries and coastal infrastructure that may be affected.
- National policy costs. Although part of the management costs, the estimated cost of developing and implementing a national policy at the government level is highlighted here, from the consultation process to the preparation of all stakeholders and creating a monitoring regime.

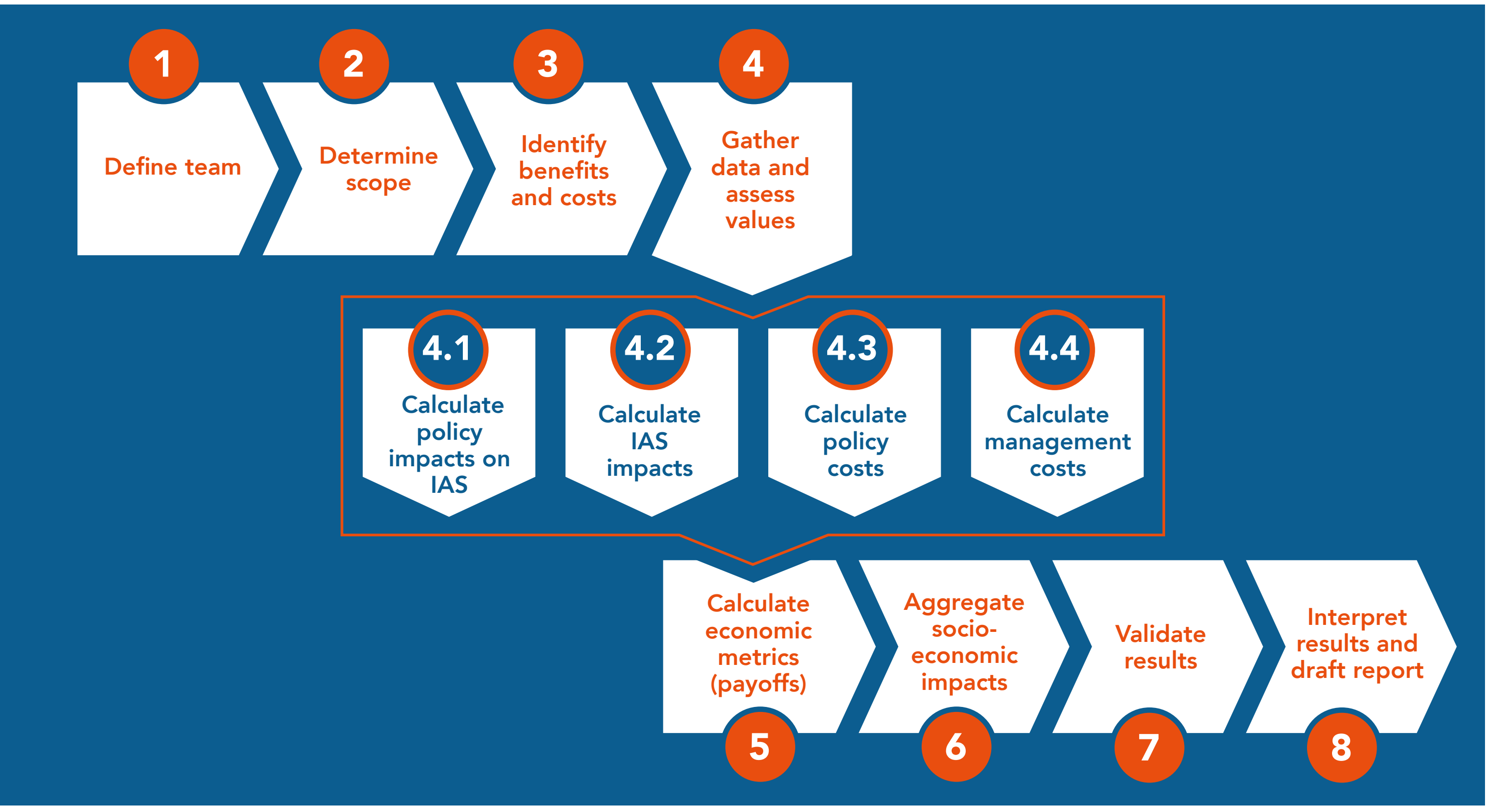
Although conceptually simple, the methodology here suggested can be challenging due to the significant uncertainties regarding magnitudes of key factors, particularly for indirect impacts and non-use values. **Table 1** in Section 1.5 explains the approach used in this Guide to provide some grounding that may account for key uncertainties and related assumptions.

The methodology prioritises the use of data and scientific information developed at the national or regional level, focusing, where possible on the use of market prices, particularly when considering maritime industries. In the absence of data or information at the national or regional level, the value transfer method should be used to estimate economic values for ecosystem services and potential impacts that cannot be valued otherwise. However, the choice should be determined by the characteristics of each case study, available data and how to deal with specific levels of uncertainty. This is implemented by transferring available information from detailed original case studies to another location or context. Economic valuation using value transfer will generate values that provide indicative potential values of ecosystem services in the region. Resulting figures should therefore be interpreted with care and transparency when introduced into decision making processes.

2.1 Steps for Developing a National Economic Assessment Report

This Guide will follow key steps to deliver a rapid economic assessment of a biofouling policy. **Figure 3** illustrates the order in which the development of the report should be approached. These steps will be addressed in detail in this Chapter.

Figure 3: Steps for the development of a national rapid economic assessment report



Step 1: Define the Team

The methodology proposed in this Guide for a rapid economic assessment can be undertaken by one person or a team of people that bring together several skills. Regardless of the number of people in the assessment team, collaboration is essential with the national maritime administration and/or the lead national agency commissioned with overseeing the development of a policy for biofouling management.

While no specialist knowledge on environmental valuations is essential for the development of the report, the assessment team should bring together the following traits:

- Relevant qualification, ideally in one or more of the following fields: marine biology, environmental economics, shipping and port operations, fisheries and aquaculture management, or maritime policy and administration.
- Demonstrated numeracy skills, including the ability to use, interpret and communicate economic data and information. Some understanding of the concept of ecosystem services and its application would be an advantage.
- Good understanding of maritime industries, particularly shipping, is required. Understanding of at least one of the other main national maritime industries (fishing, aquaculture, offshore oil and gas) would be an advantage. Familiarity with biofouling management, Invasive Aquatic Species and their potential impacts would be an advantage.
- Demonstrated abilities to identify, obtain, review, and synthesise economic data and information from multiple types of reports and publications.
- Demonstrated writing skills, with good command of oral and written English and the national official language (if different) at the discretion of the national maritime administration or Lead Agency.
- Demonstrated communication skills, with experience in the development and delivery of presentations aimed at government and/or administration representatives and the ability to develop and maintain relationships and to communicate effectively with a range of stakeholders.

Where critical skills are absent from the team (e.g., economics), oversight of work, or review of findings, by an external expert should be considered.

Step 2: Determine the Scope of the Report

Step 2 is focused on identifying industries and ecosystem services that may be affected by biofouling and/or IAS, the scope of the report and then identifying information or data needs and the sources where it may be acquired.

Although the NSA report does not focus on retrieving economic data, it will be a key source of information that will list all industries and ecosystems that are relevant to the country. In the absence of an NSA report for the country, users of this Guide should refer to the recommendations lined out in Annex C (National Self-Assessment Checklist) and Chapter 3 (Acquiring the necessary baseline information) of the Guide to Developing National Status Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species, published by GloFouling Partnerships https://www.glofouling.imo.org/publications-menu.

Care should be taken not to confuse determining the scope of the economic assessment report with the assessment of biofouling risk or determining the likelihood of an IAS introduction. The purpose of the national economic assessment is to determine the potential cost and benefits derived from not managing biofouling and the impact of IAS on ecosystem services:

- **Maritime industries operating at the national level.** Special attention should be given to industries such as shipping, fishing, aquaculture, offshore oil and gas, marine renewable energies.

Coastal ecosystems	Ecosystem services		
	Provisioning and Cultural	Regulating	Supporting
Coral reefs	Recreation and tourism, fish and shellfish harvesting, raw materials, education and aesthetics	Storm protection, nutrient cycling	Biological diversity, ecological connectivity, habitat for fish and shellfish, nursery and protective habitat
Seagrass beds and salt marshes	Fish and shellfish harvesting, raw materials, wildlife harvesting, education and aesthetics	Storm protection, erosion control, water purification, oxygen cycling, nutrient cycling, carbon storage and sequestration	Biological diversity, ecological connectivity, nursery and protective habitat for fish, shellfish and wildlife
Mangroves	Fish and shellfish harvesting, raw materials, education and aesthetics	Storm protection, erosion control, water purification, oxygen cycling, nutrient cycling, carbon storage and sequestration	Biological diversity, ecological connectivity, nursery and protective habitat for fish, shellfish and wildlife
Oyster reefs	Shellfish harvesting, raw materials, education and aesthetics	Storm protection, erosion control, water purification, oxygen cycling, nutrient cycling, carbon storage and sequestration	Biological diversity, ecological connectivity, nursery and protective habitat for fish, shellfish and wildlife
Beach, dune and shore	Recreation and tourism, education and aesthetics	Storm protection, erosion control	Biological diversity, ecological connectivity, nursery and protective habitat for shellfish and wildlife
Bays and estuaries	Recreation and tourism, Fish and shellfish harvesting, raw materials, wildlife harvesting, education and aesthetics	Storm protection, erosion control, water purification, oxygen cycling, nutrient cycling, carbon storage and sequestration	Biological diversity, ecological connectivity, nursery and protective habitat for fish, shellfish and wildlife
	LOCAL	SCALE	GLOBAL

Table 3: Coastal ecosystems and types of economic values for ecosystem services (Source: Adapted from Milan and Alvarez, 2019)

- **Associated industries.** Information on shipping should also consider the existence of associated industries, such as shipbuilding, dry-docks, ports and marinas (including service providers for biofouling management such as ship maintenance, in-water cleaning, etc.).
- **Other coastal industries and infrastructure.** Information on industries such as coastal tourism, power generation, etc., that may be affected either by biofouling and/or IAS.
- **Social and Cultural uses.** Information on the uses of coastal ecosystems and/or marine species by coastal communities, and their role in social exchange, recreation and cultural or identity aspects.
- **National biodiversity and natural resources.** The existence of coastal ecosystems of particular value that support marine biodiversity or provide specific ecosystem services at the national level. **Table 3** lists the main categories of coastal ecosystems and the different services with which they are

commonly linked. The table will Guide users to identify any ecosystems at the national level that should be included in the scope of study.

- **Development plans.** Although an industry may not be relevant to the country at the present time, it should be determined if any steps or plans are being made for future development as this may imply other costs or benefits arising from the introduction of a policy.

The approach in this guide to assessing the impacts of biofouling and IAS is centred around domestic industries and values. In theory, some values related to biofouling may have international dimensions – for example, where internationally important species are at risk of invasion. For this reason, any significant international interests in biofouling/ IAS issues should be noted in socioeconomic impacts (Step 7).

Step 3: Identify the Benefits and Costs

The impacts of biofouling vary according to the species and industry or ecosystem service concerned. The most common impacts of biofouling arise as a result of the entry of IAS to a country. This can increase costs or reduce the benefits from maritime industry sectors or ecosystems. For instance, the impact on commercial fishing may increase as access to target species is hampered by predation by IAS. In addition, some industries may experience increasing costs or falling revenues arising from biofouling. For example, fuel costs for commercial shipping may rise as a result of biofouling because greater energy is required to overcome the hydrodynamic drag created by organisms on hulls.

To clearly identify the benefits of a biofouling management policy, analysts need to identify what would happen if the policy was not implemented. This baseline situation is sometimes known as the "without" or "unmanaged" scenario. The baseline must be compared to what would happen if a new policy were implemented (the "with" or "managed" scenario). This with-and-without analysis is important when considering biofouling because:

- Its harm may change over time. For example, without a biofouling policy, a new IAS incursion may occur or – where an incursion has already begun – the costs of IAS may worsen over time as the species spreads. By comparison, with a policy, the incursion may be avoided entirely or its spread slowed.
- The impact of a biofouling policy may take time to take effect. Applying a with and without framework will allow analysts to explicitly consider the time lag between implementing a policy and avoiding the costs of an IAS.

The benefits of a biofouling management policy are therefore the difference between the costs of biofouling without the policy and the costs of biofouling with the policy. For instance, in **Figure 4** (see next page), biofouling is assumed to enable a new and harmful IAS to enter a country, such that costs rise steadily over time as the species reproduces. By comparison, with a biofouling policy, the arrival of a new IAS may be prevented entirely, so that the benefits of a biofouling policy are the total costs of incursion over time avoided (Figure 4a). Alternatively, a biofouling policy may delay the arrival on an IAS and or suppress its harmful costs over time. In this case, the benefits of a biofouling policy would be the lower total costs of incursion over time (Figure 4b).

[2] Effective biosecurity is likely to involve layers of protection, each of which reduce risks of impacts from IAS. These may include, for example pre-border measures to prevent transport of unwanted species, border-based measures to detect and intercept species before they can establish natural populations and post-border management of pest populations.

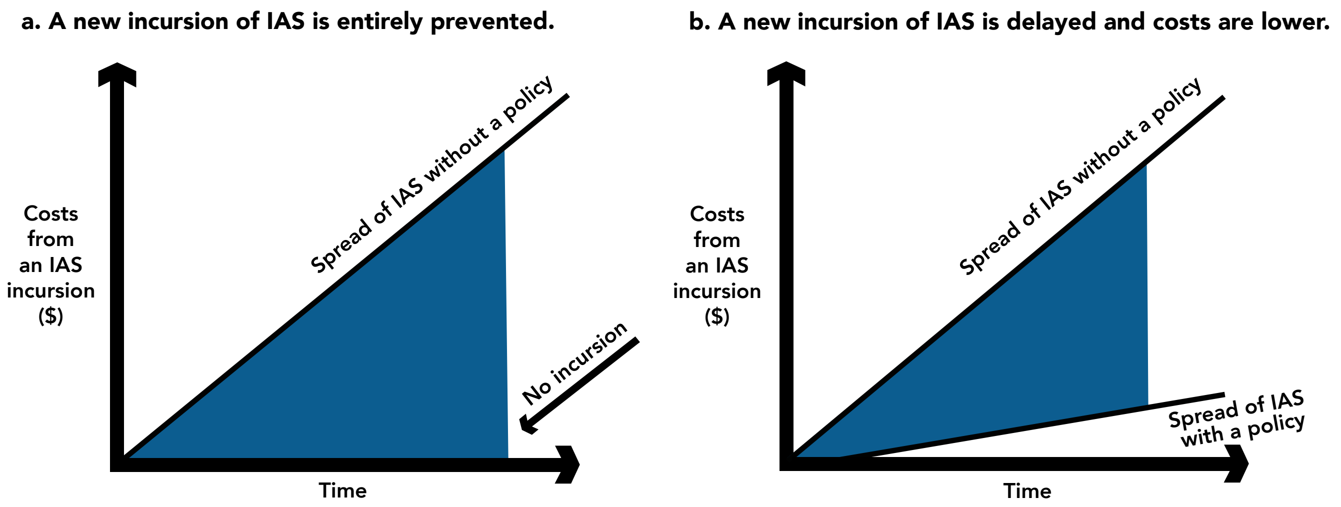


Figure 4: Dynamic change: with and without scenarios

Where a biofouling management policy prevents the introduction of a new IAS, the benefits of the policy are measured as the total costs of the species avoided. In practice, other policies such as local level pest management may be required[2] to prevent incursion. The value of the biofouling policy is then measured as the share of prevention that the policy achieves (for instance, the introduction of the policy may be responsible for reducing the threat of incursion by 50 per cent). In the same way, where IAS have already commenced incursion, the introduction of a biofouling policy may slow down further entry. The benefits of a biofouling policy are then measured as the share of reduced spread/entry that the policy secures.

To prepare the analysis, analysts could answer the following questions for each species of IAS they use to evaluate the new policy:

- Will a biofouling policy prevent a new incursion of the IAS?
    - If yes, the benefits of the policy will be 100 % of the cost of an IAS incursion avoided.
- If no (i.e.., the species already exists or is introduced despite the policy) will a biofouling policy slow further spread an IAS?
    - If yes, the benefits of the policy will be a proportion of the reduced spread (between 1 and 100 %) (**Table 4**).

Table 4: Benefits of a biofouling management policy

	Policy contributes to preventing a new incursion	Policy contributes to spreading an existing incursion
Policy benefit	Between 1 and 100 per cent incursion costs	Between 1 and 100 per cent costs of further spread

In addition to the above, while some industries may not be particularly affected by IAS (e.g., shipping), the levels of biofouling on their surfaces could be directly related to the risk of introducing or spreading IAS. In this case the with and without scenarios can be qualitatively assessed using **Table 5**, below:

Table 5: Other benefits of a biofouling policy

Industry name	Policy (adopting improved biofouling prevention and management measures) contributes to reduced operational costs or increased profit margins
	Yes/No

Finally, the costs of a biofouling management policy make take several forms:
- Policy development costs (e.g., costs of drafting a national strategy, costs of consulting the public and other entities, cost of baseline reports, etc.)
- Costs of implementing the policy (e.g., capacitating key stakeholders, policing ports, records monitoring and management, etc.).

Guidance on how to estimate the cost of developing and implementing biofouling management policy are provided in Chapter 4.

Identify Priority Values To Quantify

As quantification of values can be a time-consuming process, analysts can save time in economic assessment by prioritising major variables to assess. Analysts should consult literature or experts to:
- Identify all main sectors/values that are likely to be affected by a biofouling management policy.
- Qualitatively rate the impacts of biofouling and IAS on industries and resources at risk, according to expected significance. This may need to be done in consultation with sectoral experts.

This work enables analysts to identify up front the sectors where the greatest impact is likely to be achieved through valuation so that time can be used most effectively. The listing is also helpful to remind analysts which values they do not quantify which is important in the validation of findings (Step 6). Following this Guide, analysists might achieve this work by competing **Table 6** in the course of their assessments.

Step 4: Gather data and estimate values

Step 4 entails securing the information and values to support the development of estimations and/or calculations. To minimise uncertainty and assumptions, priority should be given to data and values from national sources, particularly in relation to maritime industries.

In instances where data is not available by other means, preferred options to secure data are, in order of preference:
1) Use of the value transfers based on case studies from the Database. The use of the Database of case studies is explained further below.
2) The use of expert opinion. This can be used when considering the expected impact of biofouling or IAS on costs and or changes in costs arising from improved biofouling management, where no suitable case studies can be found. A sensible approach would be to secure a range of values from experts, for example, a 'best' case and a 'worst' case range.
3) Hypothetical or illustrative changes in biofouling costs. These should only be used as a way to identify the kinds of risks at stake when understanding is insufficient for even experts to hazard informed estimates if values. In this case, a range of values should be considered to cover 'best' and 'worst' cases

Table 6: Qualitative rating of values

	Likely value/significance (h, m, l)	Rationale for rating	Priority to attempt valuation (highest, lowest)
Commercial shipping			
Aquaculture			
Commercial fishing			
Etc.			

so that the implications of a biofouling might can be identified. This option also provides a means to estimate the scale of impact reduction that might be needed to justify investing in a biofouling policy (that is, what benefits would be needed to cover the cost. In other words, this approach could indicate the benefits needed to enable a policy to 'break even'). Hypothetical values should ideally be identified in discussion with experts.

Where no data is available or considered appropriate to use, the values concerned should be listed and described, including consideration given to whether the values are likely to be sizeable or not (and why).

These approaches produce increasingly indicative estimates of value and should be presented as such in the report write up (Step 9). Where no information can be secured, or reasonable estimates are not possible, values should always at least be listed and described. (Refer to the suggested report template in Step 9).

What information is required?

Chapters 3 and 4 provide detailed information on the type of data that might be used to estimate the values of biofouling and associated IAS in different sectors. However, in general terms, data needs can be divided into the following categories:

Table 7: Type of information required for each category

Category	Type of information required
Maritime industries	**Shipping, Ports and Marinas, Aquaculture, Fishing, Marine renewable energies, Offshore mining.** Key industry data, such as industry size, types of infrastructure, main production lines or types of products. Volume and key production costs, particularly maintenance cost and asset replacement costs in relation to biofouling prevention and impacts. Additionally, any information (either in reports or sourced verbally from relevant stakeholders) on the presence of IAS in any industry and its relationship with additional operating costs (maintenance or business adaptation), production losses and reduced revenues (due to, for example, lower product quality).
Other industries and coastal infrastructure	**Recreational boating, tourism, coastal infrastructure, biofuels and food components.** Key data, such as industry size, size and main types of infrastructure, main production lines or types of products. Volume and key production costs, particularly maintenance costs in relation to biofouling prevention and impacts. Additionally, information on the presence (and if possible) the additional impact IAS caused in any of these industries and their infrastructure.
Indirect use and Non-use values	Information on social and cultural uses of marine species or habitats, existing recreation groups related to coastal or marine environment (not tourism), option values (e.g., potential **pharmaceutical and Cosmetics uses), Environmental impacts and non-uses.** Research focusing on the use and valuation of marine and coastal ecosystem services at the national or regional level.
Invasive Aquatic Species	Information on the presence of IAS (confirmed or suspected), both in national waters and in the vicinity (neighbouring countries or maritime region). Data should preferably include a description of known or possible impacts (environmental and/or economic).
Government costs	In very general terms, the overall cost of developing and implementing a national policy, including average cost of consultations and meetings, such as meeting venues, cost of time spent using prevailing average monthly salary for civil servants, government officials (such as PSC officers) and industry stakeholders participating in the development and implementation of the policy, cost of training government officials, cost of a communication and awareness campaign, etc..

Where available, prices and references should be sourced from materials, reports and research conducted in the country or region of study. Products and services related to maritime industries are directly traded in markets, or in a certain way replace products usually obtained in a (local) market or store. Therefore, their value is best assessed using the local market prices that would need to be paid for the replaced product. These differ from country to country and region to region significantly but are relatively easy to obtain and provide a much more precise idea of the actual, local value of the service.

The next two flowcharts provide a graphic review of the process and when to use or not the List of Case studies or the List of economic valuation studies.

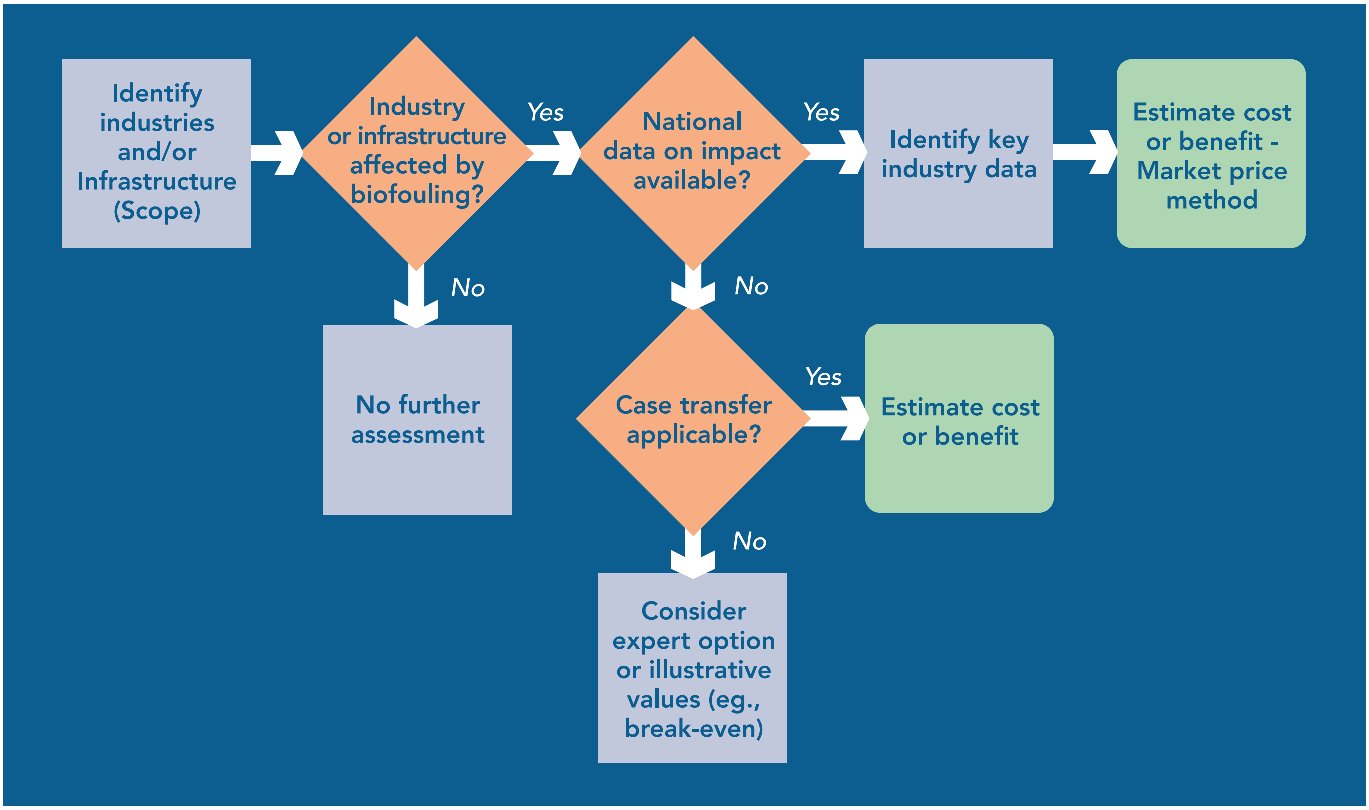


Figure 5: Flowchart for assessing the economic impact of biofouling on national industries and/or infrastructure

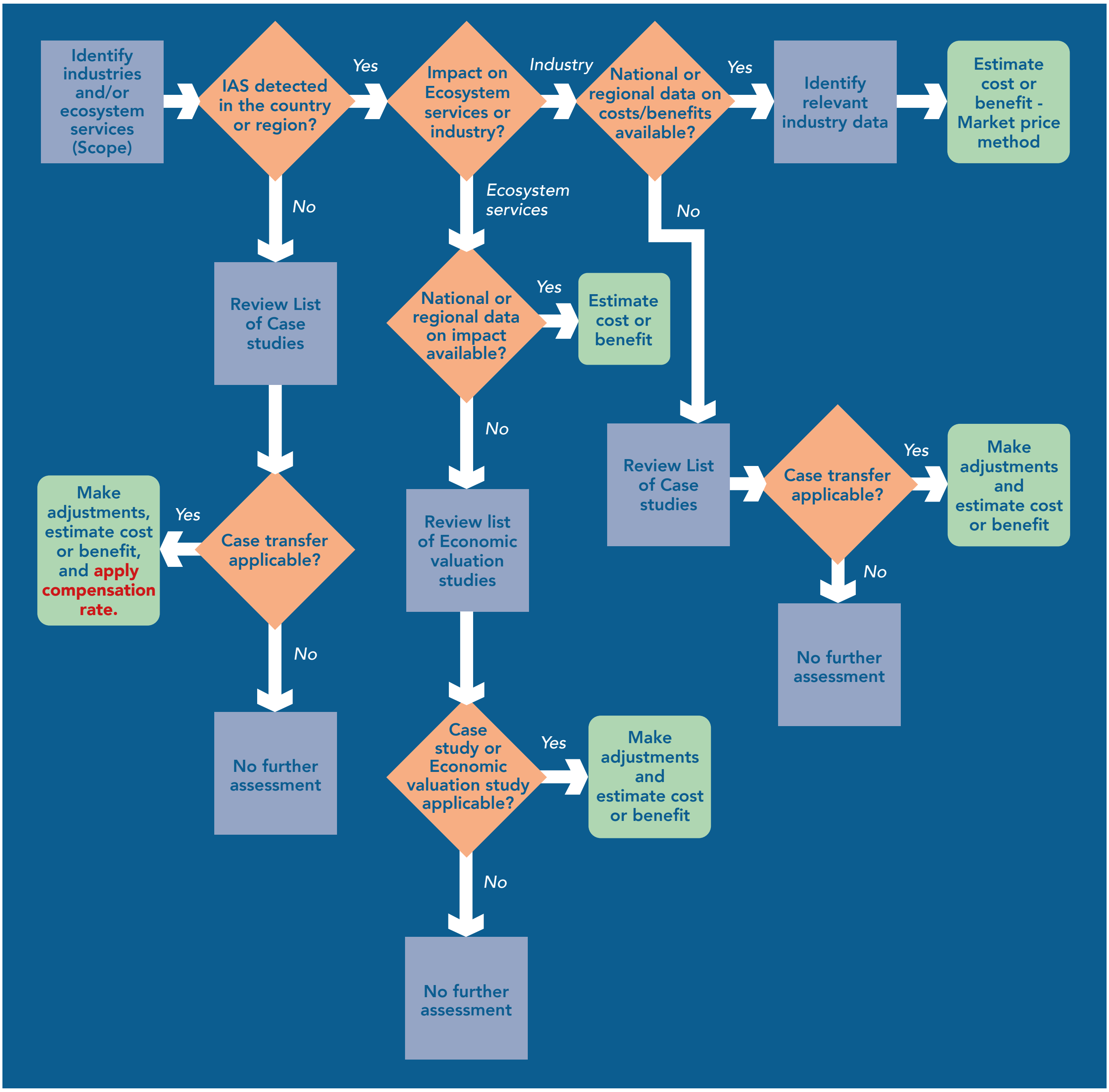


Figure 6: Flowchart for assessing the economic impact of IAS on national industries and/or ecosystem services

Sources Of Information

For Lead Partnering Countries of the GloFouling Partnerships, the main resource should be the National Status Assessment (NSA) report, where essential information, sources and references should have been compiled. Nevertheless, for all countries, most data will be retrieved from national statistics and reports published by government agencies or ministries, industry associations and academic or research institutions. Additionally, entities represented in the national task force will point out towards key stakeholders to be considered for the purpose of securing data.

In the absence of a NSA report, information on maritime industries, coastal infrastructure and the use of marine resources should be available from ministries (Fisheries, Marine and Coastal Management, Environment, Energy, etc.); industry associations (e.g. fishing and aquaculture industry associations, shipping and port associations, mining associations, sailing associations); universities and marine research centres, and relevant CSOs and NGOs. Additionally, information on IAS may be found in some of the main international databases available online, such as CABI, Nemesis, the IUCN Global Invasive Species Database, the World Register of Marine Introduced Species and AquaNIS.

Information on tourism should be available from the tourism ministry and/or related agencies at national, regional or local levels. Coastal municipalities may also be able to provide, for example, information on numbers of beach users and different activities on and around beaches.

Links to other sources of information specific to each maritime industry are provided under each section in Chapters 3 to 7. In the absence of information at the national level, the Database of case studies, provided as a separate file, can be used to identify suitable data that may be used for a case transfer and/or a value transfer. Additionally, the NSA Guide, published by the GEF-UNDP-IMO GloFouling Partnerships, provides a general reference list of resources that may be used.

In all likelihood, the area where analysts will be most challenged to access reliable data will be when trying the quantify the change in IAS costs resulting from the introduction of a biofouling policy. Nevertheless, information may also be very scarce when dealing with new species or changing environmental conditions.

As indicated, where information is extremely lacking, data may be drawn in the following ways, in order of preference:

- From value transfer case studies of the management of similar species from overseas.
- From consultations with experts as to their opinions of change. In these cases, a range of values should be identified and the minimum values used for conservative estimates. (Maximum ranges can be used in sensitivity analysis – see Chapter 2: Step 6) The use of expert opinion in economic analysis will need to be accompanied by reference to the name, title and credibility of the expert concerned.
- Hypothetical/ illustrative changes. This approach is relevant only where understanding of the impact of biofouling and an IAS is extremely poor and even experts are uncertain about impacts. In this case, posing a hypothetical change impact can be useful to illustrate the kinds of risks at stake and to consider the levels of change needed to make a policy worthwhile (that is, to determine the benefits needed to make the policy breakeven)
- Where no data is available or considered appropriate to use, listing and description of values, including consideration given to whether the values are likely to be sizeable or not (and why).

As these approaches are highly indicative, their use should be highlighted in the report write up (Chapter 2, Section 9).

When And How To Use The Database Of Case Studies

This section provides indications on how to search for existing studies and values that can be used for a case or a value transfer, via the Database of case studies. The Database is available online https://docs.google.com/spreadsheets/d/10ACMgMz9u_VN-deS0gS7xzgee-pQoCj3/edit?usp=sharing&ouid=117300532281063966085&rtpof=true&sd=true and contains two types of resources:

a) **List of Case studies.** Information on economic impact cases of IAS, which provide examples in monetary terms of their effects on different maritime industries or ecosystems.
b) **List of Economic valuation studies.** Information on valuation studies that quantify the benefits of diverse ecosystem services.

The two lists included in the Database are considered directly usable to transfer cases or values to another area. It is the result of an extensive search, screening hundreds of cases and valuation studies and selecting the few that are directly usable. The Database is structured to easily identify the studies available for case or value transfers, select the most appropriate ones, and to have all information at hand to perform any adjustments to the values cited that might be necessary.

How to use a Value Transfer

There are two different types of values that may need to be transferred: the nature and scale of baseline values at risk and the nature and scale of IAS impacts. IAS case studies generally report both the impact and the baselines.

As mentioned in section 1.4, when assessing the impact of IAS on maritime industries, priority should be given to the use of data and values retrievable at the national level. However, in the absence of information at the national or regional level related to the impact of IAS, it may be possible and appropriate to adapt data sourced from other cases. **Table 8** illustrates when and how it is suitable to apply case studies from elsewhere to inform an analysis. Additionally, these values may need some treatment before use at the national level in another country (this aspect is explained in the following sections of this chapter).

Table 8: General rules for transferring values

How to transfer impact values		
Scenario	**Adaptation required**	**Action**
IAS identified in the country or region, impact assessment available and quantified.	NO	
IAS identified in the country or region, impact assessment available, but no quantification.	SOME	• Calculate impact on maritime industry or infrastructure: using local prices. • Calculate impact on ecosystem service using local value of ecosystem service if available – if not, determine baseline with value transfer (see last row).
IAS identified in the country or maritime region but no impact study available.	YES	• Use List of Case studies to identify impact studies with similar IAS • Calculate impact on maritime industry using local prices and industry size. • Calculate impact on ecosystem service using local value of ecosystem service if available – if not, determine baseline with value transfer (see last row).
No IAS identified in the country or region, but maritime industry or ecosystem identified as high exposure or national dependence.	YES	• Use list of case studies to identify cases with same industry or ecosystem and study area characteristics • Calculate impact on maritime industry or infrastructure: using local prices. • Calculate impact on ecosystem service using local value of ecosystem service if available – if not, determine baseline with value transfer (see last row). • Due to high level of uncertainty, use assumed (0.25) Invasion rate (page 22) to avoid excessive weight.
How to transfer baseline values-at-risk		
Scenario	**Adaptation required**	**Action**
Baseline value of ecosystem services available locally (from national or regional research or report).	SOME	• Use baseline value determined locally. • Adapt to current prices if required • Aggregate to national level if required

Table 8: General rules for transferring values - continued

How to transfer baseline values-at-risk		
Scenario	**Adaptation required**	**Action**
Baseline value of ecosystem services not available.	YES	• Use list of economic valuation studies to identify similar ecosystem • Adapt to local context considering differences in population and ecosystem significance.

Baseline Ecosystem Value Transfers

The **List of economic valuation (EV) studies** should be used when no valuation exists at the national level for a specific ecosystem service that has been identified as (potentially) impacted by an IAS. In this case, the List of EV studies provides access to over almost 100 international economic valuation studies form marine and freshwater ecosystems that can be used to identify a similar scenario as in the country of study. The list provides the following information:

- Authors/name of the study/year.
- Marine or freshwater ecosystems: whether the study covers marine or freshwater, or both, ecosystems.
- Specific ecosystems covered: which specific ecosystems are covered by the study (e.g. mangroves or sea- grass beds/meadows).
- Ecosystem and study area characteristics: some information on the specific site under consideration, if available (such as size or whether an assessed wetland is situated in an urban area or a national park; this information is highly dependent on the quality of the study at hand).
- Ecosystem services covered: the specific ecosystem services covered by the study (e.g. moderation of extreme events; see also the earlier tables).
- Valuation Method(s) used: the methods used to evaluate the ecosystem services assessed.
- Values per area (i.e. per hectare) monetary unit used (year): the "core information", i.e. the results the study lists regarding the values of the specific ecosystem services, presented as "values per hectare per year", to allow an easy transfer to another area.
- Monetary unit used, and which year (for adjustments of currency and inflation).
- Socio-economic characteristic: population density of the area (low/medium/high, to allow an adjustment of the values in a value transfer).
- Socio-economic characteristic: per capita income (national level 2015, to allow an adjustment of the values in a value transfer).
- Socio-Economic characteristic: density of use by tourists/visitors (highly visited/medium/rarely, to allow an adjustment of the values in a value transfer).
- Warm or cold-water ecosystem (to allow an adjustment of the values in a value transfer).

The studies found should be checked and assessed – the PDF versions of the original studies are to be found in the last column of the table (via hyperlink).

To select a suitable Value transfer, studies from the list which roughly fit the area of study need to be identified. For example, if there is an area composed mainly of mangroves and seagrass beds to evaluate, a selection of all studies evaluating these two ecosystems is available in the list.

The next step is to decide which of the selected studies can be used for the value transfer, i.e. the aim is to select the ones with a best fit. For example, analysts should decide which studies include the ecosystem services that need to be evaluated and determine whether the economic values from the case study can be transferred to ('fit') the area under consideration.

In order to do this, a set of criteria - characteristics and traits of the area/areas which are evaluated in the study/studies taken from the list - will guide through the process. Basically, the characteristics of the study area should be as similar as possible to the area considered for the report. When deciding whether the existing values are transferable, the following criteria are important to demonstrate that the case study and existing area match well:

- Per capita income does not differ by more than 100% (i.e. it should not be less than half and not more than double as high).
- The area must have similar economical uses, i.e. fisheries etc.
- The intensity of ecosystem service use by tourists/visitors must be similar.
- Warm and cold-water ecosystems values should only be transferred to the same unless there is evidence the transfer is appropriate.

Case Transfers

The **List of case studies** provides access to almost 50 studies of IAS where an impact has been identified and estimated for a maritime industry or marine and freshwater ecosystems. The list provides the following information:

- Authors name of the study/year.
- Title of the study.
- Marine or freshwater ecosystems: whether the study covers marine or freshwater, or both, ecosystems.
- Specific ecosystems covered: which specific eco- systems the study covers (e.g. mangroves or sea- grass beds/meadows).
- Ecosystem and study area characteristics: some information on the specific site under consideration, if available (such as size or whether an assessed wetland is situated in an urban area or a national park; this information is highly dependent on the quality of the study at hand).
- Name of the IAS.
- Description of impact.
- How does the IAS spread.
- Ecosystem services covered: the specific ecosystem services covered by the study (e.g. moderation of extreme events; see also earlier tables).
- Valuation Method(s) used: the methods used to evaluate the ecosystem services assessed.
- Values per area (i.e. per hectare) monetary unit used (year): the "core information", i.e. the results the study lists regarding the values of the specific ecosystem services, presented as "values per hectare per year", to allow an easy transfer to another area.
- Monetary unit used, and which year (for adjustments of currency and inflation).

The case studies found should be checked and assessed - the PDF versions of the original studies are to be found in the last column of the table (via hyperlink).

To select a suitable case transfer, the first part would be to identify studies from the list with an IAS or industry that is similar to the one existing in the country under study. When deciding whether the case study is transferable, the following criteria is regarded as crucial:

- Name of species (or broad taxonomic group) identified in country or region.
- Ecosystem and industry or study area characteristics are similar or at least identified as having high exposure. This is a value judgement that should be justified in the assumptions listed in the final report with the support from marine biology specialists.

If there are no suitable studies that fit the specific case at hand, it may be required to consider using other indicative approaches of value, such as drawing on expert opinion or even listing and describing the values concerned, including considering whether the values are likely to be sizeable or not.

Examples of for the application of Case and Value transfers is provided in Chapter 3.

When using these examples, careful consideration should be given about their applicability to the country or region of study (existing industry, similar exposure or risk, etc.).

Adjust Values

Four forms of adjustments may need to be made to estimated values, including when considering those from the case studies:

- Remove market distortions from any financial (market) values used.
- Where case studies are used for value transfer, values may need to be adjusted to:
  - Convert values to the correct currency at constant prices,
  - Convert them to present day rates,
  - Where appropriate, account for differences in purchasing power.
- Adjust price levels. Where values obtained from other countries will be adjusted to the country of study purchase power parity.

Figure 7 illustrates the adjustments that need to be considered for each value determined through Step 4. All adjustments are explained in the nest three sections of this chapter. The notation page of the calculation tool will facilitate making the adjustments keeping track of the information added in this step, as well as the final result.

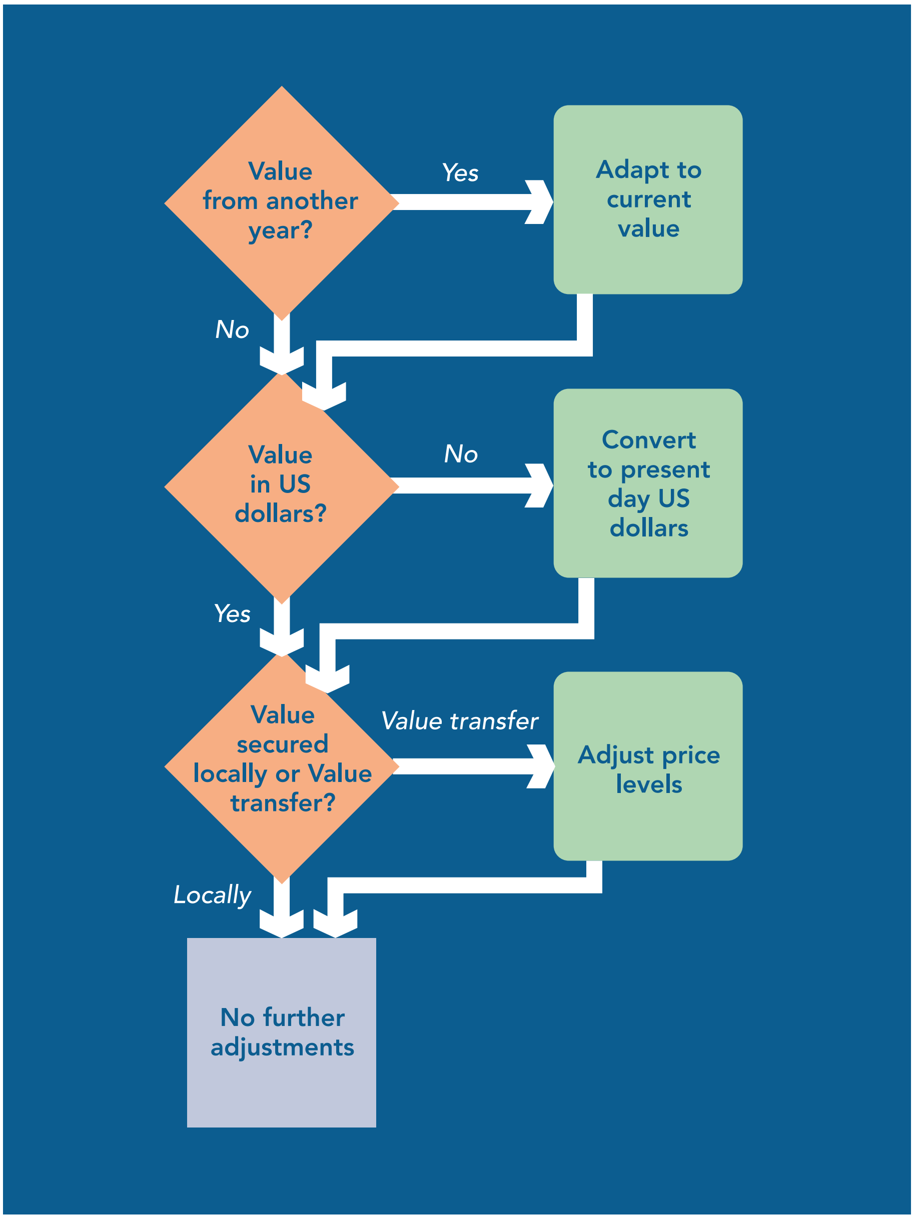


Figure 7: Adjusting to net present value

Benefits	Include all benefits in the year they occur
Costs	Include all costs in each year they occur (capital, labour, operating, maintenance, training and all other input costs)
Environmental and other externality costs	Include
Capital (credit) costs	Include when capital is invested
Depreciation	Exclude (because these are accounting charges)
Taxes	Generally exclude
Subsidies on production cost	Generally exclude
Government or donor costs	Include
Family labour	Include as opportunity cost
Unpriced benefits and costs	Include
Environmental and health costs	Include

Table 9: Items to include or exclude from economic analysis

Remove Distortions from Financial Values

There is considerable similarity between financial and economic values which explains the value of turning to market prices to estimate economic values in an economic analysis. Nevertheless, market imperfections mean that financial prices are not always the same as economic values. For example, markets do not indicate the value of environmental changes while taxes and subsidies artificially raise or lower the apparent values of market goods while not affecting the nature of the item itself. These forms of distortions need to be corrected when determining economic values from financial prices. Some key considerations are noted in **Table 9**.

Adapt To Current Values

Constant prices are set at a point in time, whereas current prices imply an attempt to forecast prices in future years. In practice, the latter is only done where there is high price variability, the effect has a significant impact on the outcome of the analysis and, most importantly, when there are reliable means to forecast future price changes.

Therefore, constant prices are generally preferred for this kind of assessments. If constant prices are used throughout the analysis – for future years as well as the initial year – then resources will be consistently valued at prices reflecting their value in alternative use at the present time. Future economic effects will be measured in the same units as present effects, and the relative comparison of costs and benefits at any point in time will be valid.

For the purpose of securing constant prices, the assessment will need to choose a reference year that will be considered as present-day value. To avoid as much as possible an unnecessary increase in the number of adjustments, the year selected would normally be the one used in the latest or most common national reports – generally the year before the current year. Additionally, and for to ensure that the outcome of the study is comparable to other countries, this Guide recommends conversion of all values to present-day US dollars (USD).

To achieve the aforementioned:

- Values need to be converted to current values. Where all values will be adjusted to the reference year using the inflation index.
- Values need to be converted to present-day USD. Where all values will be converted using the USD conversion rate prevailing in the reference year.

The values stated in the value transfer study are transformed into current values, using the appropriate inflation rate (in most cases of the country in which the study was conducted). The inflation rate is always stated as a percentage, e.g. "2%".

Inflation rates according to the Consumer Price Index (CPI) should be employed, a method which compares the cost of things that the average household buys, such as food, housing, transportation, medical services, etc., over the years. For earlier years, it is the most useful series for comparing the cost of consumer goods and services. It can be interpreted as how much money is needed today to buy an item in the year in question if its price had changed the same percentage as the average price change.

The following specifications apply:

- For studies that used revealed or expressed preference methodologies (travel cost, hedonic pricing etc), the CPI/inflation rate of the country in which the value transfer study was conducted will always be used.
- For studies that used cost-based approaches (e.g. damage costs, replacement costs) in the currency of the country in which the value transfer study was conducted, also the CPI/inflation rate of this country will be used.
- For studies that used cost-based approaches (e.g. damage costs, replacement costs) in USD or €, the CPI/inflation rate of the United States or the Euro zone will be used, respectively.

The CPI inflation rate for the USD can be calculated easily via the following website: https://www.bls.gov/data/inflation_calculator.htm

The CPI inflation rate for the Euro zone and several other industrial or semi-industrial countries can be extracted via the following website:

- Current inflation: https://www.inflation.eu/inflation-rates/cpi-inflation.aspx
- Historic inflation: https://www.inflation.eu/inflation-rates/historic-cpi-inflation.aspx

The inflation rates of the last years are displayed in a summarized way only in the CIA World Factbook:
https://www.cia.gov/the-world-factbook/

Example. How to adapt values to current value

The study to be used for value transfer dates from 2014 is from Cameroon. It uses a cost-based approach, e.g. analyzes the replacement costs for flood protection measures to determine the economic value of riparian wetlands. The values are stated in the national currency of Cameroon, the CFA franc (XAF), and are at 10,000 CFA/ha.

The task is now to adapt the 2014 XAF value to its current, 2019 value.

The inflation rates for Cameroon are stated on the website CIA World Factbook (see link above): 1.9% in 2014, 2.7% in 2015, 5.3% in 2016 and 5.2 in 2017. The calculation would be as follows:

2014: 10,000 + (1.9% = 190) = 10,190

2015: 10,190 + (2.7% = 275) = 10,465

2016: 10,465 + (5.3% = 555) = 11,020

2017: 11,020 + (5.2% = 573) = 11,593

The resulting 11,593 XAF/ha is the current value (beginning of 2018 – information for 2018 still not available) in local/national currency.

Convert to present-day US dollar

The present value of the value transfer study calculated in step 1 (see page 25) is converted into its equivalent value in present-day USD. If the original study is already in USD, this step can be skipped. For the conversion, the following websites are recommended:

- https://www1.oanda.com/currency/converter/
- http://fx.sauder.ubc.ca/data.html
- https://data.oecd.org/conversion/exchange-rates.htm#indicator-chart
- https://www.xe.com/currencytables/

Example. How to convert values to present-day US dollars

In the example in step A, the study area is located in Cameroon, and the values are stated in the national currency of Cameroon, the CFA franc (XAF). From step A, 11,593 XAF/ha is the current value in local/national currency (beginning of 2018 – information for 2018 still not available).

Using one of the references provided above, the average exchange rate for XAF to USD in 2018 is 574.93. The calculation would be:

11,593 XAF / 574.93 = 20.16 USD/ha

Adjust price levels

Through this conversion, the difference in price levels between the value transfer site and study area are accounted for. This is done by comparing the gross domestic product (at purchasing power parity) per capita (GDP PPP). Comparisons of national wealth are frequently made on the basis of nominal GDP and savings (not just income), which do not reflect differences in the cost of living in different countries; hence, using a PPP basis is more useful when comparing generalized differences in living standards between nations because PPP takes into account the relative cost of living and the inflation rates of the countries, rather than using only exchange rates, which may distort the real differences in income.

The following specifications apply:

- For studies that used revealed or expressed preference methodologies (travel cost, hedonic pricing etc.; the methodology used is listed in the repository for each study), this methodology will be used.
- For studies that used cost-based approaches (e.g. damage costs, replacement costs; the methodology used is listed in the repository for each study) in the currency of the country in which the value transfer study was conducted, also this methodology will be used.
- For studies that used cost-based approaches (e.g. damage costs, replacement costs) in USD or €, this step will be skipped, as it can be assumed that values/ prices stated in the original study reflect more global than local prices (which are the same in both countries 6).

Box 5: Absolute and relative values

Data retrieved for this report may come in two different forms: an absolute value of a specific ecosystem service (e.g. "total value of all fish catches in the area"), or a relative value (e.g. value per ton caught or "value per m^3 harvested"). To help quantify costs for this report it is important that adequate transformation is made from relative to absolute values. For this you need to calculate the absolute value by multiplying the value per kg/ton/m^3 with the overall amount produced or harvested.

A list of countries rated according to the GDP (PPP), based on IMF and World Bank data, can be found at Wikipedia[3] - it is recommended to use this list as a basis, because extracting the information from IMF or WB databases can be difficult:

The adjustment is done by calculating the ratio in GDP between the value transfer site and the area which is being studied, resulting in a factor that will be applied to the current USD value calculated in the steps 1 and 2 (see page 25).

Example. How to adjust price levels

The study area is located in Cameroon, whose GDP (PPP) per capita in 2018 amounted to 3,828 International Dollars (IMF data). The ratio is calculated by relating this number to the GDP (PPP) of the value transfer site in Vietnam, with a GDP (PPP) per capita in 2018 of 7,510 International Dollars (IMF data):

Cameroon 3,828 / 7,510 (Vietnam) = Factor 0.509

This factor should be applied to the current USD value resulting from the calculation in steps 1 and 2.

20.16 USD/ha x 0.509 = 10.26 USD/ha

Step 5: Estimate Present Day Values and Economic Metrics

Discount Values

Having estimated benefits and costs in economic terms, economic metrics of efficiency of a biofouling policy will be generated. To do this, the spread of benefits and costs over time will first need to be addressed for values in both the with and the without scenarios. Most policy investments involve costs early on to develop the policy, whereas benefits may not be manifest for some time. This variation in when values occur affects how countries view them. People tend to value costs or benefits accrued in the future less than those accrued at the present time. Therefore, it is important to account for this distribution of costs and benefits over time. The practice of accounting for this time preference is called discounting and involves valuing future financial costs and benefits in terms of their present value. It is the inverse of compounding interest.

The common way to treat temporally distributed values is to apply a discount rate to future values so that they can be compared as "present values". Discounting is done by multiplying future values by a discount factor 1/(1+r)t. That is:

$$PV = {FV}/{(1+r)^t}$$

where
PV = present value
FV = future value of benefits or costs
r = discount rate
t = time period

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 often has a significant impact on the outcome of the analysis (for more information see Khan and Green, 2013). Whatever discount rate is chosen, it should be noted that benefits and costs occurring in later years will have a lower present value.

Various respected organisations provide advice on the discount rate to be used.

[3] https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita

For example, the UK Treasury guidelines recommend a discount rate of 6% for public sector policies, while for most environmental and social impact studies a rate of 3.5% is recommended. More information on the subject can be found in the following links:

- The Green Book. Central Government Guidance on Appraisal and Evaluation (UK, 2018)
- US Environmental Protection Agency (EPA) website

Where possible, and for the purpose of this economic assessment, the discount rate should be selected based on the prevalent use in the country that is being analysed. Nevertheless, and considering that the choice of discount rate can have a large impact on the findings of a valuation study, a sensitivity analysis using two different discount rates can be applied to check how it influences the results. Below is also an example on how this is applied to a simplified scenario.

Example. Estimating the present value and analysing the impact of the discount rate on time series

For the first example we will use one discount rate of 2% and analyse the impact on the costs estimated over 5 years for the implementation of a government policy. The calculation is based on the following Government costs related to policy:

- One off cost in 2021: 1 million – As 2021 is considered present, this figure does not need to be discounted
- One off cost in 2022: 1 million – As 2022 is one year in the future, the present value of this figure would be: 1,000,000/(1+0.02)1 = 980,392
- Other implementation costs: USD 500,000 every year – As this is an annual cost, the discounted time series resulting from applying the same formula over 5 years would look as follows:

2021	2022	2023	2024	2025
500,000	490,196	480,584	471,161	461,923

The present value for the 5 years would be 721,159. Calculating the total Government costs over 5 years would look like this:

2021	2022	2023	2024	2025	Total
1,000,000	0	0	0	0	1,000,000
0	980,392	0	0	0	980,392
500,000	490,196	480,584	471,161	461,923	2,403,864
				Grand total	4,384,257

The second example will explore the impact of two discount rates (2 and 6%) on the NPV and analyse their effect across two different time frames (5 and 10). Let's assume that we have also determined the following costs and benefits:

Without policy - Costs and benefits of biofouling and/or IAS

- Costs to ecosystem services due to IAS: 5 million per year
- Benefits due to IAS: 1 million per year
- Costs to Shipping industry (national): 6 million per year

With policy - Costs of biofouling management and prevention

- Costs to Shipping industry: 3 million per year
- Plus the government costs calculated in the first example further above

Example. Estimating the present value and analysing the impact of the discount rate on time series - continued

Calculating the present value for all the variables will render the table below. It is worth to highlight how the higher discount rate (6%) has a strong impact on present values in the long term (15 years), with a difference of almost 20 million when compared to r=2%.

r = 2%	5 years	10 years
Without policy	48,077,287	91,622,367
With policy	18,807,443	34,180,580
r = 6%		
Without policy	44,651,056	78,016,923
With policy	17,571,266	29,561,260

Analysts are required to discount all values (benefits or costs) that arise in the future so that the values are expressed in present day terms. Importantly, analysts only discount values that are expected to happen in future year(s) (not this year).

Generate Economic Metrics

Cost benefit analyses typically generate a range of metrics to demonstrate the efficiency of investments. These include, net present values (NPV), internal rates of return, benefit: cost ratios as well as various social payoffs. For the purpose of the rapid biofouling work reflected in this Guide, it is recommended that the net present value of the biofouling policy under consideration be the focus. The NPV of a biofouling policy option is the present value of all benefits from the policy less the present value of costs, summed over the lifetime of the project. This can be represented mathematically as:

$$NPV = \sum_{t=0}^{T} PV\,(Benefits - Costs)_t$$

where

NPV = net present value
PV = present value of investment over time
t = time period (e.g. year)

A policy with an NPV greater than zero provides net economic benefits to a country. This means that overall – i.e. from a whole-of-society perspective – the gains generated from the project outweigh the losses incurred. Conversely, a project with an NPV less than zero means that the project will generate a net loss for society – that is, the losses incurred outweigh the gains generated. Further, the greater the NPV, the more efficient the outcome, meaning the more benefits are generated from the costs of the resources used.

Step 6: Assess Socio-Economic Impacts

The appraisal of the economic costs and benefits derived from the introduction of IAS or the implementation of a prevention strategy is only one aspect of the social issues and processes associated with IAS that need to be considered. The social and cultural implications of the policy should also be considered from an economic perspective to provide insight into any equity or potential impacts that might affect the acceptability, design or potential funding (cost sharing) opportunities in the policy.

In an ideal world, a social analysis would be conducted of prospective policies. For the purpose of a rapid assessment in this Guide, it is recommended that:

- An overview of distributional issues by conducted at a qualitative level, by completing **Table 10**: Overview of distributional issues, It is at this point that any international interests in biofouling (e.g., cultural concerns about critical species) might also be noted.
- A basic gender analysis be conducted by completing the questionnaire in **Table 11**.

Table 10: Overview of distributional issues

Stakeholder	Reason for interest	Stake (low, medium, high)
E.g., hull cleaning industry	Existing employment levels, sunk investments, profits	M
E.g., Cultural fishing (beach gleaning)	Widespread gleaning conducted by women for additional community protein, with remainder sold at the local market and funds being used for family welfare,	M-H
Etc.		

Table 11: Example of Gender impact assessment questionnaire

Does the economic assessment identify differences in the roles and needs between women and men in relation to activities that could be impacted by a policy on biofouling management ?
Will prevention measures related to biofouling and IAS improve equally the productivity of women and men?
Will the policy improve or impair access to resources by men or women?
Will the policy improve or impair the control of resources by men or women?
Will the policy improve or impair the share in the benefits by men or women?
Will the policy improve or impair the control of the benefits by men or women?
Will the policy improve or impair participation in decision-making by men or women?
Does the policy include any factors that may inhibit women's full participation in management measures? How may they be overcome?
Based on findings in previous questions, would a policy on biofouling management have a different impact on women and men?
Based on findings in previous questions, would a policy on biofouling management help to empower women or undermine their current position?

Adapted from FAO (2001) p. 45.

Box 6: Impact of IAS on gender

Shell fishing on foot is predominantly women's work and an important generator of wealth in Galicia, a region in northern Spain. According to the local administration, out of the 3,792 licensed shellfish gatherers on foot in Galicia - 71.78% of them are women. Women shellfish gatherers are active social agents with important work not only in their fishing activity but also in the conservation of protected natural areas where they fish (selective extraction, beach care, etc.)

In the last 10 years clams are not proliferating as they once did in the shellfish banks of the region. The shellfish gatherers blame the disaster on snails native to the Pacific, the Ocinebrellus inortatus, which in Japan eat only oysters but in Galicia have expanded their diet and affect any bivalve they come across, be it cockles, razor clams, clams or mussels. Additionally, since 2008 the region has suffered an invasion of "cañaíllas" (Bolinus brandaris) and "busanos" (Hexaplex trunculus), two molluscs of Mediterranean origin. Although both species can be marketed, it is difficult to find buyers. In the meantime, local clams are being wiped out.

A Galician fishermen's guild has put figures on the economic impact of the phenomenon - each invasive species can eat around three kilos of bivalve molluscs per year. In a recent removal campaign, 147,320 individuals of these invasive species were collected, which would mean the loss of some 441,960 kilos of clams valued at around 8.2 million euros. The fight against these species includes hiring a company every year to remove their nests during the months of May and June. Shellfish gatherers also join in the work, but their feeling is that the expansion is unstoppable. Their presence is concentrated in the inlets and efforts are currently focused on preventing them from expanding to the rest of the coast. Sailors and fishing boats are warned to be cautious because they can get them caught in the nets as biofouling.

Beyond these economic impacts is the question of how this may affect women's income, their ability to remain within the sector and the social ties and support that underline their activity. Women's economic empowerment sets a direct path towards gender equality, poverty eradication and inclusive economic growth. The effects can spread across families and communities. Research indicates that women invest more of their income on family needs such as food, medical care, and schooling, improving opportunities for the next generation. Therefore, the impact of IAS in this box could clearly go well beyond the economic value of lost resources.

Step 7: Validate Results

Estimates of the economic costs of biofouling or the expected benefits of a policy should be validated prior to finalisation. This can be done using a variety of simple approaches:

- Basic reality testing,
- Sensitivity analysis,
- Peer review.

Reality Testing

Reality testing involves taking key major values from the analysis and comparing them to known values to see how logically they compare. For example, a simple test might be to compare the estimated total costs of biofouling for a sector to its GDP to ensure that the proportions of costs to overall worth seem logical. Where proportions seem incongruent, analysts may need to double check their values before proceeding further.

Sensitivity Analysis

A sensitivity analysis tests how reliable (robust) the results of the cost benefit analysis are when assumptions or short cuts have had to be used because of imperfect data. A sensitivity analysis should be conducted for all major assumptions or short cuts. In the case of a biofouling policy, sensitivity analysis is likely needed where:

- Transfer values from case studies were used and there were a range of values that might reasonably be applied,
- Expert opinion has been used,
- Hypothetical values have been used to illustrate the potential impactions of a biofouling policy.

In these cases, alternative reasonable values (such as the best or worst-case values) should be applied to identify whether the study findings are robust. For example, it should be determined whether a positive NPV remains positive or whether a negative NPV remains negative. Any variation is key assumption that changes the NPV changes the policy implication. These cases should be highlighted as it means that the study findings are not robust.

Peer Review

Especially where an economist does not form part of the assessment team, it would be sensible to seek a review of the analysis from an economist, if one can be accessed. Aside from the value of 'fresh eyes' to an analysis, economic peer review will provide a quality check for the application of economic costing and rules. Where economists are not available locally, some regions or countries may have institutions where economists may be accessed (such as the Pacific Resource and Environmental Economist Network (PREEN) located at IUCN Oceania[4]).

Step 8: Interpret Results

There are three major interpretation steps in a rapid analysis:

1. The economic viability of the proposed biofouling policy of the NPV needs to be addressed:
   - First the NPV without the sensitivity analysis should be interpreted. A policy with an NPV greater than zero indicates that a country benefits overall from the introduction of a biofouling policy – in other words, that the policy is economically viable. Conversely, A policy with an NPV less than zero indicates that a policy is economically inviable.
   - Any major assumptions that were used to generate the value – such as the use of values transferred from other case studies or expert option – should now be considered. Analysts should identify whether major assumptions used may have overestimated or underestimated any values – and whether the overall NPV may therefore be higher or lower.
   - Consideration should now be given to any key values (e.g., sectoral impacts) that were not quantified in the analysis (see **Table 8**, page 34). Analysts should identify whether the omission of these values is likely to have underestimated or overestimated the NPV presented. Based on these considerations, analysts should conclude (i) whether or not the policy is likely to be economically viable (that is, whether the NPV is likely to be positive or negative) (ii) the likely scale of the NPV.
2. The robustness of the results needs to be addressed. The analyst needs to recognise that any variation in key assumption that changes the viability of a policy means that the study findings are not robust. In this case, further information is needed to determine whether or not a biofouling policy is efficient from an economic perspective.
3. The socioeconomic assessment findings should be considered in terms of whether any major interest groups will be substantially negatively impacted by the policy. If so, this would likely affect public support for the policy. There would likely be a need to refine the design and implementation of the policy to minimise harm.

When interpreting results, it should be emphasised that economic analysis should not lead to a recommendation to implement policy. Economic viability is not a policy justification. Policies are based on the basis of factors other than economics – such as politics, palatability etc. The findings of the CBA will not be a recommendation to invest or not – but to advise if the investment appears to be economically viable and to identify any implications for the Realisation of benefits.

Step 9: Draft the Report

Decisive uses of valuation studies in policy seek to evaluate the trade-off between different levels and/or types of ecosystem services. A summary of the results

[4] https://www.iucn.org/regions/oceania/our-work/promoting-and-supporting-effective-and-equitable-governance/natural-resource-economics

grouped by sector will often be sufficient for providing an overall comparative analysis of how an investment in preventing IAS through implementation of a biofouling policy compares to possible costs as a result of incursions when not taking any action. Nevertheless, although further elaboration or analysis may not be required in many cases, a brief written summary should be prepared to highlight areas of particular concern, key uncertainties detected, and the main assumptions made for developing the economic assessment.

The aim of the brief report is to convey the main findings and provide some recommendations to policy decision-makers. Language should be simple and concise, prioritising the delivery of key points that may help a non-specialist audience to assess the different options at hand within a policy. Using simple graphic representations of key points should also be considered to present data, if feasible. It is also important to provide sufficient information on how data was obtained and an explanation of analytical procedures, assumptions and uncertainties.

The following template aims to target a concise report that can draw from the Excel tool and does not exceed ten pages. However, it is also important to be aware of the limitations of the data and the constraints this may place on the analysis. The approach presented in the report should not yield the kind of information required for advanced analysis: findings should thus not be considered nor presented as a detailed economic valuation, but rather as a broad, 'brush-strokes' overview.

GloFouling PARTNERSHIPS

Template for a National Economic Assessment Report

Economic impacts of biofouling and Invasive Aquatic Species

Summary for policymakers

Estimated economic viability of a biofouling policy:	***Viable*** or ***Not Viable***

Background to assessment

1. Biofouling and Invasive Aquatic Species threats

Brief description of what is biofouling and Invasive Aquatic Species with specific mention of the recommendations of the National Status Assessment Report and the overall outcome (NPV) of this national economic assessment (making reference to any chart or graphic that may serve to summarise the results – see suggested graph below, and if relevant, any other information that should be highlighted at the top of the report)

Suitable graph or chart summarising the outcome of the report. (for example, a graph/chart with 5,10 and 15-year of the PV curve; or comparing the with and without policy scenarios

Total economic impacts (in US dollars or national currency)	Cost of policy (in US dollars or national currency)

2. Industries and resources at risk

Short description of existing maritime industries, facts and figures, with a brief description about their exposure, importance to the national economy and future perspectives, as per the table below.

Where data is available and relevant, potential impact on employment should also be mentioned in this section.

3. **Potential impacts by industry compared to the cost of preventive measures (in USD or national currency)**

Maritime industries	Output per year	Impact of biofouling and/ or IAS (i.e. without policy)	Management costs (with policy)
Shipping			
Ports and marinas			
Aquaculture			
Fishing			
Marine renewable energies			
Offshore mining			
Recreational boating			
Tourism			
Coastal infrastructure			
Biofuels and food			
Pharmaceuticals and cosmetics			
Environmental impacts and non-uses			
Recreational			

4. **Other resources or sectors at risk**

Brief description of other values such as human wellbeing or religious issues

5. **Estimated economic payoffs and considerations for a biofouling policy**

- *Total present value of biofouling (and associated IAS) without a policy*
- *Total present value of biofouling (and associated IAS) with a policy*
- *Gross benefits of a biofouling policy:*

Total present value of biofouling (and associated IAS) without a policy -
Total present value of biofouling (and associated IAS) with a policy
Gross benefits of a biofouling policy

- *NPV (total present value without a policy less total present value with a policy, less costs of policy[5])*
- *Observation of estimated NPV and implications for economic viability of a policy*
- *Observation of the robustness of the analysis:*
  - *General statement on methods used, e.g., where transfer values and expert option were applied*
  - *Statement on the findings of the sensitivity analysis and overall robustness of values*
  - *Brief description of any major uncertainties and assumptions identified in Step 5*
  - *Completed table on assumptions and unpredictabilities for concerned sectors*
- *List of key values not quantified and expected impact on actual NPV (including completed table on Unquantified Values)*
- *List of critical further information needed to make a decision (if the analysis is not robust enough to confidently view a policy as economically viable)*
- *Observation of socioeconomic ramifications:*
  - *any key 'losers' in the policy and the potential need for further consideration of policy design*
  - *completed table of Distributional Analysis*

[5] Costs of implementing policy and other costs as relevant.

6. Unquantified Values

Sector/value not valued, general context	Rationale for not assessing	Likely significance of value (H, M, L, unknown)	Likely impact on NPV (increase/ decrease/ unknown)

7. Distributional Analysis

Stakeholder	Reason for interest	Stake (low, medium, high)

8. Consideration of social aspects

Brief conclusion on the outcome of any assessments made as per step 6, particularly any focused-on gender dimensions

9. Other government policy considerations

Brief description of the main costs of implementing a national policy. This should also include:

- *work already underway,*
- *potential costs and benefits from the government perspective*
- *national budget allocations potentially required and*
- support from national stakeholders

10. Sources of error

Maritime industry	Data description or aspect	VUCA category	Likely significance as a source of error
Shipping	e.g. savings in hull cleaning costs	Volatile (values vary)	Low
Recreational boating	e.g. number of recreational boats	Uncertain (information is not available)	Medium
Environmental impacts	e.g. impact on biodiversity	Ambiguous (no information exists)	High

11. Assumptions and confidence concerning sectors

Maritime industries	**Value estimated**	**Measurement approach e.g., sector specific assessment, value transfer, hypothetical value**	**Calculation used**	**Data sources**	**Confidence in estimate (based on sources of error table) e.g., high, medium, low**
Shipping	E.g., Savings in hull cleaning costs	E.g., Author estimate	E.g., Market price of hull cleaning x # vessels,	e.g., market data, published government vessel data	E.g., high
Ports and marinas					
Aquaculture					
Fishing					
Marine renewable energies					
Offshore mining					
Recreational boating		E.g., Values transfer	E.g., USD x x # recreational vessels	E.g., Case study database	E.g., medium
Tourism					
Coastal infrastructure					
Biofuels and food					
Pharmaceu-ticals and cosmetics					
Environmental impacts and non-uses		E.g., Illustrative value	E.g., policy cost/ # users	E.g., Expert opinion	E.g. low
Recreational		E.g., values transfer	E.g., # users x willingness to pay for clean beach	Case study database	
Other (as relevant)					

12. List of value transfers used

Sharing the Outcome of the Report

Before its publication, it is recommendable that the main findings included in the National Rapid Economic Assessment report should be reviewed and validated by the Lead Agency that may have commissioned the development of the report. Should it exist, the National Task Force for Biofouling Management would be another entity that could review the report and validate its contents.

Once the report is endorsed by the Lead Agency, the report should be presented to relevant policy decision-makers and stakeholders within national maritime industries that may be affected by biofouling and/or IAS.

To present the report, the authors should develop a short presentation that should include the following points:

- What is biofouling, illustrating how it affects a wide range of maritime industries.
- How biofouling is a vector for Invasive Aquatic Species and its relationship with GHG emissions from shipping
- Background conducting to commissioning the report commission (why was it commissioned; the team developing the report)
- Main outcome of the report: Total potential impacts and estimated cost of a national policy
- Potential impacts by industry compared to the cost of preventive measures
- Brief description of the main costs of implementing a national policy.
- Summary of recommended measures and/or next steps

The presentation should be concise, avoid the use of excessive text and prioritise the use of suitable tables or simple graphic representation. The language should be simple and concise, prioritising the delivery of key points that may help a non-specialist audience to assess the different options at hand within a policy. It is also important to provide sufficient information on how data was obtained and an explanation of analytical procedures, assumptions and uncertainties.

3 Calculating Costs and Benefits for Industries

This part of the Guide provides detailed information on key data and parameters related to biofouling values that need to be assessed for maritime industries, other uses and non-uses, as well as how to cost the development and implementation of a national policy. Estimation of the potential costs of biofouling and associated harm from IAS is initially centred around estimating the cost of a new incursion of IAS (or the benefits of avoiding it). Where introduction of a biofouling policy does not solely prevent a new incursion of IAS, the benefits of the policy will be less than 100 per cent the cost of an IAS incursion avoided. As indicated in Chapter 2 Step 4, information on the share of biofouling / IAS costs reduced by biofouling policies may be gleaned from:

- Use of the case studies Database which contains examples that may be used for Case and Value transfers. The use of the Database of case studies is explained further in this chapter.
- The use of expert opinion. This should only be used when considering the expected impact of biofouling or IAS on costs and or changes in costs arising from improved biofouling management. A sensible approach would be to secure a range of values from experts, for example, a 'best' case and a 'worst' case range.
- Hypothetical or illustrative changes in biofouling costs. These should only be used as a way to identify the kinds of risks at stake. A range of values should be considered to cover 'best' and 'worst' cases so that the full range of implications can be identified. Hypothetical values should be identified in discussion with experts.

Where no data is available or considered appropriate to use, the values concerned should be listed and described, including consideration given to whether the values are likely to be sizeable or not (and why).

3.1 Appraising the Shipping Industry

The shipping industry is not generally perceived to be noticeably affected by IAS (other than biofouling), so an economic impact specifically related solely to an IAS would not be expected. However, economic costs can arise in the form of cost and effort required by the shipping sector to prevent biofouling and/or clean ships' hulls to manage it. Therefore, in the case of the shipping industry the focus of this estimation will be to calculate the potential economic harm:

- from biofouling without a biofouling management policy, and
- the potential reduction in economic harm from having a biofouling management policy (benefits or reduced operating costs)

Without Policy Scenario

Table 12 (next page) details the main types of information that should be secured during the data gathering step to estimate the costs of economic harm of biofouling to the shipping industry in the absence of a policy that may facilitate the industry to adopt improved biofouling prevention and management measures.

The fishing fleet (both large and small vessels), auxiliary and drilling vessels in the offshore oil and gas industry, auxiliary vessels in the aquaculture industry and port service vessels will follow a similar method of calculation. However, the results should not be included in this section, but in the calculation for their respective industries or sub-sectors.

Table 12: Data requirements and sources of information for the shipping industry

Type of information	Specifications	Sources of information
Shipping fleet composition	Collect information on number of ships per ship type and size category within a country's fleet, taking into consideration two different fleet components: • Registered fleet: vessels registered in the country, regardless of whether they are actively trading in the country or not. • Number of affected domestic vessels or % of total fleet servicing the country's domestic transport demand by moving goods and people from one port of the country to another port of the country likely to be affected. In addition, consideration may be given to: • Vessel owned by national shipowners: ships owned by companies registered in the country. Data should be grouped using the same categories listed in Annex A.	• National Status Assessment report (if available). • National Maritime Registry of Shipping: vessels registered with this classification engage in international transport and transport on the inland waterway systems. • River registry: this registry contains vessels registered for transport on the national inland waterway system. It is expected that for some countries, only nationally registered vessels will be permitted navigation/trade on the country's inland waterway system. • Relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), port authorities and from the shipping companies themselves. • IMO's Country Database and Clarkson's World Fleet Register: can also be utilised to generate the technical specification of vessels and also for any gap filling in these areas. • HIS Sea-web Directory. • UNCTAD Country maritime profile
Port-based services	Prevailing prices for: • Hull cleaning and grooming services: prices and service costs will vary considerably from one country to another and should be sourced from local companies offering this type of services. Prices should consider both diver-based and ROV-based services. • Drydock and port fees. Prices and service costs will vary considerably from one country to another and should be sourced at least from within the region. • Antifouling coatings: prices and service costs should be sourced from local dealers and dry-docks or using national websites of main manufacturers or distributors of antifouling coatings.	• Relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), port authorities and from the shipping companies themselves. • Dry docks, manufacturers and service providers available in the country (or, if unavailable, in the region).
Revenue and OPEX	Average time charter rates for main ship categories and types. OPEX and revenue per day for most ship categories.	• Shipping companies and operators. • Reports from relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), port authorities. • UNCTAD • Time charter rates: https://www.hellenicshippingnews.com/weekly-tanker-time-charter-estimates-march-17-2021/

Table 12: Data requirements and sources of information for the shipping industry - continued

Type of information	Specifications	Sources of information
Fuel prices	Identify an average price for the main fuel type available in the country or nearest source. While bunkers IFO180 and IFO380, consideration should be taken about using for cleaner fuels such as MGO 0.1% or VLSFO max 0.5%.	• Relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), port authorities and from the shipping companies themselves. • Bunker prices: https://shipandbunker.com/prices • Bunker prices: Bunker Fuel Prices Today, IFO 380, IFO 180, MGO Prices per Ton, Live & Historical Charts (oilmonster.com) • Average bunker fuel prices: https://www.bunkerworld.com/prices/

Figure 5 (see page 31) and the further sections present the main parameters to be considered for calculating the impact of biofouling and IAS on ships. This is followed by a detailed explanation of each parameter and some examples.

Costs related to biofouling and IAS	**Impact on assets:** • Increased hull and propeller roughness • Increased niche area clogging and corrosion of internal seawater systems **Impact on operations:** • Non-compliance of hull with national or local standards or regulations • Non-compliance of vessel in carrying IAS	**Economic cost:** • Increased fuel consumption • Increased maintenance/ repair costs (e.g., engine cleaning) • Loss of revenue (operational days) • Additional GHG emissions • Cost of inspections and/or fines

Increased Fuel Consumption

Fuel costs are still the major operating cost for all major ship types, and with legislation driving the use of potentially higher priced clean fuels, the cost of operating vessels is going to remain high. Controlling fuel costs and GHG emissions is now an important consideration for all ship operators. Fuel consumption is proportional to the power generated by the ship's engine to move it through water. Power is needed to overcome hydrodynamic resistance. While overall resistance is made of many factors, it is the skin frictional resistance that is the major contributor. Therefore, controlling skin friction by creating and maintaining smooth hulls and propellers is vital.

Biofouling on ships is the main source of increased roughness and frictional resistance of their hull. Other impacts to be considered are the potential clogging of cooling water intakes that may affect engine performance. There are many references about the impact on drag and how this penalty would increase fuel consumption. In a landmark study made on a whole class of US Navy vessels (Arleigh-Burke class – 9,000 t, length 150 m), Schultz et al. (2011) estimated that a biofouled hull uses between 10 – 20% more fuel. They concluded that maintaining a clean hull could save the US Navy between USD 1.2 and 2.3 million per annum in fuel costs for each ship in this class, for scenarios that included just heavy slime with no hard fouling in the first case, and relatively small hard fouling for the second case (USD of 2009). However, and due to the variety of ship designs and characteristics, there is no single accepted efficiency metric that could be used for all ships to allow a clear and uncontested benchmarking of a whole fleet of vessels. ICES (2019) estimates that even moderate biofouling is linked to a 11–21%, power increase, while heavy calcareous biofouling requires a 35–86% power increase to maintain the same speed as a clean hull.

In a survey of internationally arriving vessels conducted in New Zealand (Inglis et al, 2010), non-indigenous species were found in approximately 60% of the vessels. The study concluded that there was a positive relationship between a vessel's biofouling extent and the number of NIS present. Although most vessels surveyed carried out biofouling management activities, large variations in the predictability of fouling occurrence are indicative of significant variability in the quality of management applied.

A more recent survey (Safinah, 2020) identified 44% of surveyed vessels with over 10% hard fouling on underwater hull surface covered with hard fouling. On many of the vessels surveyed, fouling levels were even worse: approximately 15% of vessels had between 10-20% of hard fouling coverage on the hull, 10% of vessels had 20-30% of hard fouling coverage and the remaining 10% of vessels had between 40-80% of hard fouling coverage.

The Fourth IMO GHG Study (IMO, 2020) proposes two average scenarios for CO_2 emissions growth, one based on a business-as-usual average and the other based on a high energy efficiency average. It is assumed that an average 10% of the High Energy Efficiency gains will be due to the three measures related to biofouling management (i.e. advanced hull coating to reduce fouling, propeller polishing to reduce propeller roughness and hull cleaning to reduced hull roughness). The percentage proposed for this calculation is based on the estimated reduction of 5 to 23% presented in a White Paper published by ICCT and also using the estimates documented in the IMO-commissioned LR and DNV Study (according to this report, out of the total SEEMP related measures, the hull conditions could account for 8.66% to 13.06% of total CO2 reductions, depending on various ship types and sizes). However, these studies are based on estimations for international shipping, where prevalence of hull maintenance is considered high.

A more recent report (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022) analyzed and compiled the results of most scientific reports on the impact of biofouling on the energy efficiency of ships. This indicated that the impact of biofouling on the fuel efficiency of ships may have been underestimated, with results such as up to a 25% penalty for slime layers or even up to 55% for hard fouling.

Based on the above considerations and for simplification purposes, this Guide recommends the use of 20% increased fuel consumption across all ship types due to poor biofouling management. Again, it should be noted that an exact calculation would depend on many variables, such as the type of hull, level of biofouling, navigation speed, etc.

Box 7: How to estimate the fuel penalty for a national fleet

Three potential methods are available for estimating the fuel penalty for ships registered under a flag State. The decision on which method to be used should be based on the practicality of obtaining the required data within a reasonable time frame and the calculation effort.

A list of the main ship types and sizes and average fuel consumption per year can be retrieved from Annex A. To avoid duplications or double counting, fishing vessels and support vessels for oil and gas and mining industries should not be included in the list, as they will be considered under other maritime industries. This is also applicable where possible, to support vessels for ports and the aquaculture industry.

For all methods, the calculation of the biofouling penalty should be based on the following:

Increased fuel consumption due to biofouling = $\sum S_T \times C_y \times P \times R$

S_T - Number of ships registered (broadly divided into main ship types and sizes - as in Annex A

C_y - Average fuel consumption per year/ship type (in tonnes)

P – Bunker oil price per tonne (at closest location)

R = 20% - Assumption of fuel penalty due to poor biofouling management

Box 7: How to estimate the fuel penalty for a national fleet - continued

Method 1: Data reported by ship owners or operators
This entails obtaining annual data for fuel consumption of all ships (or a representative sample) registered in the country directly from ship owners. The resulting list of ships and annual fuel consumption should be used for the calculations described further below in the examples. Due to the potential difficulty of obtaining this information for a large fleet, this method is only recommended for countries with a limited number of ships or limited ship types.

Method 2: Estimation through ship energy calculators
A number of commercially developed programmes and databases allow the estimation of the effect of biofouling on individual ships. To apply this method, information on installed engine power, fuel types consumed, auxiliary power, etc. In order to report yearly statistics on fuel consumption, these data sources need to be aggregated across the different ships and the voyages made by the ships. Due to the potentially difficulty of obtaining this information for a large fleet, this method is only recommended for countries with a limited number of ships or limited ship types. A software license may also be required to access this type of tools.

Method 3: Estimation based on remote monitoring (bottom-up method)
A simplified method for calculating the increased fuel consumption across the whole fleet of ships registered in a country, is based on estimates of fuel consumption and emissions retrieved from data sources describing shipping activity and ship technical characteristics. The primary source of vessel activity used is AIS data which describes, among others, a ship's identity, position, speed and draught at a given time-stamp. This data can be used to build time-histories of shipping activity, which could be deployed, in conjunction with the technical specifications of a ship, in the calculation of time histories of estimated fuel consumption and emissions. This approach follows the bottom-up method and uses data identified for the Fourth IMO GHG Study (2020). To use this method, all ships for the country should be grouped using the list under Annex A. Average consumption will be obtained from the same category listed under Annex A.

The case used throughout the examples on pages 57 and 58 assumes a country that has only 23 registered ships and all are containers of an average 2,000 TEU. For each country, we recommend using a table similar to the one below example to list the different types of ships and sizes registered under their flag. Alternative formats are also possible to use, so long the list of vessels is documented.

Example. Calculating the impact of biofouling on fuel consumption using method 3

Ship type	Size	Number registered	Avg Fuel per year ('000 tonnes)	Estimated fuel per year ('000 tonnes)	20% fuel increase due to biofouling ('000 tonnes)	Avg fuel price	Cost increased fuel consumption due to biofouling
Container	0-2,999 TEU	23	5.05	23 x 5.05 = 116.15	116.15 x 20% = 23.23	508 USD/ mt (2020)	23,230 x 508 = **11,800,840**
Use list in Annex A	Use list in Annex A	Number of ships under this ship type and size, for the country chosen in this example	Using list in Annex A	Number of ships x Avg fuel per year		VLSFO max 0.5% (price obtained locally or from other references	

Using the example on page 57, and assuming that a country has no other vessels, the entry in the notation would be as follows:

Example. Including the impact on fuel consumption in the shipping industry

Industry or ecosystem	Source of information or reference	Reference value and details	Area of value (where relevant)	Year (of value, not reference)	Industry item or ecosystem service selected	Assessment by MP or VT	Cost increased fuel consumption due to biofouling
Shipping	Country ship register; IMO GHG 2020	Not applicable	Not applicable	2020 (as per the value of fuel)	Fuel consump-tion	MP	USD 11,800,840

Additional GHG Emissions

The additional greenhouse gas (GHG) emissions associated to the increase in fuel consumption calculated in the previous section, should also be considered as an additional cost related to poor biofouling management. While at the time of writing this would not entail an additional operating cost for the ship owner, future measures aimed at reducing GHG emissions from ships may contemplate the allocation of maximum levels of emissions per ship, similar to the method applied for other industries.

Of course, for different types of fuel, there are different carbon contents and, consequently, different correction factors. **Table 13** displays examples of carbon content by fuel type which may provide a start for assessments.

Table 13: Carbon content per fuel type (Source: IMO (2009))

Type of fuel	Reference	Carbon Content	CF (t-CO_2/t-Fuel)
Diesel / Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206
Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.15104
Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.1144
Liquefied Petroleum Gas (LPG) Propane;	Propane	0.819	3
	Butane	0.827	3.03
Liquefied Natural Gas (LNG)		0.75	2.75

When considering which factor should be used to estimate emissions, the Third IMO GHG Study for the year 2012 assumes that ships use Heavy Fuel Oil with a CO_2 emissions factor of 3,114 kg CO_2 /tonne fuel. Prices of carbon emissions can be retrieved from the EU Emissions Trading system, which was set up in 2005 as the world's first international emissions trading system for carbon credits.
An alternative method of calculation would be based on the assumption that many ships can be equipped with scrubbers. Estimations based on the cost and lifespan of a scrubber (Kranz, 2016) determined that the mitigation cost of 1 tonne of CO_2 would be approximately 50 euros.

Box 8: How to estimate the cost of GHG emissions for a national fleet

A common method for estimating the cost of additional GHG emissions would be based on applying the market value or sale price of carbon credits that could represent avoided emissions. The calculation should be based on the following:

Cost of additional GHG emissions $= \sum S_T \times I_B \times C$

S_T - Number of ships registered (broadly divided into main ship types and sizes - as in Annex A

I_B - Increased fuel consumption per year/ship type (in tonnes)

C – Carbon emission market price (per tonne)

Below continues with the example case presented in the previous section and shows how to calculate the cost of increased GHG emissions due to biofouling.

Example. Calculating the cost of additional GHG emissions

Ship type	Size	Number registered	Avg Fuel per year ('000 tonnes)	Estimated fuel per year ('000 tonnes)	20% fuel increase due to biofouling ('000 tonnes)	Avg Carbon emission market price	Cost increased GHG emissions due to biofouling
Container	0-2,999 TEU	23	5.05	23 x 5.05 = 116.15	116.15 x 20% = 23.23	35 USD/mt (2020)	23,230 x 35 = **813,050**
Use list in Annex A	Use list in Annex A	Number of ships under this ship type and size, for the country chosen in this example	Using list in Annex A	Number of ships x Avg fuel per year		Retrieved from markets	

Using the example above, and assuming that a country has no other vessels, the entry in the notation table would be as follows. (As indicated earlier, alternative formats to recording the list of vessels is also possible)

Example. Including the impact on GHG emissions in the shipping industry

Industry or ecosystem	Source of information or reference	Reference value and details	Area of value (where relevant)	Year (of value, not reference)	Industry item or ecosystem service selected	Assessment by MP or VT	Estimated value (calculation)
Shipping	Country ship register; IMO GHG 2020	Not applicable	Not applicable	2020 (as per the value of fuel)	GHG emissions	MP	USD 813,050

Other Economic Loss Due to Biofouling

This section helps to calculate the opportunity costs derived from a ship not being able to operate for short periods of time due its level of biofouling or a poor quality of its biofouling management plan and record book. In this scenario, a ship may risk being held for inspection or refused entry into a port by the national administration. It could include restrictions/alterations of vessel itinerary within the recipient country. This could entail loss of revenue due to additional navigation days, lengthy inspections and mandatory cleaning, part replacement, etc. Flow on effects to movement of goods (logistics), port time, and associated penalties for breaches of contract, could also exist. It should be noted that any estimation of economic loss should also take into account potential reduced fixed and variable costs, such as reduced staff expenditure (although normally only applicable for long idle periods of a ship) or reduced fuel consumption while not operating at sea. The calculation should be based on a single ship and then extrapolated to the number of national ships engaged in international trade or a percentage of the country's fleet.

Box 9: How to estimate the other economic costs

Charter arrangements in the shipping industry can make it difficult to determine the economic cost of forced idle periods. The calculation should be based on the following:

Economic cost = Reduced gross profit + Additional costs incurred - Additional income from new operations or services

Reduced gross profit = Lost revenue - Reduced variable costs - Reduced fixed costs

- Revenue: Freight rates are highly variable, not only per ship, cargo type and route, but also from year to year, influenced by demand, political and security scenarios and weather conditions. Nevertheless, the proposed formula requires an estimate of the average revenue per ship. In an ideal scenario, this data which should be sourced from local ship operators. In the absence of data at the national level, estimations for container ships could use the average freight rates for Maersk and Hapag Lloyd in 2018 were USD 940 and 1,044 TEU for the Shanghai-US West coast route. For the same year, UNCTAD reports rates in the range of USD 822 to 1,402 per TEU for long range transport (UNCTAD, 2019).
- Other options for this calculation could be based on the price of time charters. A time charter is the hiring of a vessel for a specific period of time; the owner still manages the vessel but the charterer selects the ports and directs the vessel where to go. The charterer pays for all fuel the vessel consumes, port charges, commissions, and a daily hire to the owner of the vessel. Although the contractual aspects of a time charter are varied, it could generally be accepted that Idle periods of the ship due to biofouling could normally be attributed to the ship-owner. Daily rates for time charters are based on ship types and sizes (and even the type of fuel).
- Reduced variable costs: reduced fuel consumption during days docked or idle time in relation to biofouling.
- Reduced fixed costs: typically, reduced crew costs (wages and other) due to long idle periods, lower cost of maintenance and repairs, etc.
- Additional costs incurred: hull inspection and cleaning costs; docking costs, including dock-side services; spare parts and replacement costs (for example, sensors, etc).
- Additional income: for the case considered here, with unplanned short idle periods, it is unlikely that a ship could generate additional income from other operations and services.

Example. Calculating economic loss

This example follows the case proposed in the previous sections (see example on page 57), for a country with only 23 registered ships of the same ship type (container) and same size category (all under 2,000 TEU). The calculation in the next example is based on one single ship and, therefore, the outcome should be multiplied by the total number of ships under that same category. The scenario under consideration, assumes that a container ship of 2,000 TEU, has been retained for 7 days for inspection and cleaning, due to an unacceptable level of biofouling detected on its hull. In addition, and although not included in this example, fines could be applied to the vessel by the port state. Example Calculating economic loss (see page 61) illustrates this calculation with the same example vessel used earlier in this section.

Example. Calculating economic loss - continued

LOSS OF REVENUE

Ship type	Size	Avg days at sea	Avg TEU per year	Avg freight rate per TEU	Daily revenue per ship	Idle days inspection & clean	Loss of revenue
Container	2,000 TEU	208	(208 / 21) x 2,000 = 19,809	1,000	(19,809 x 1,000) / 208 = 95,235	7 days	7 x 95,235 = **666,645**
		Using list in Annex B, or estimation from ship operator	Based on average voyage times long haul (21 days)	Estimation from ship operator	Avg TEU per year x Avg freight rate per TEU	Assumption	Number of idle days x Daily revenue per ship

REDUCED VARIABLE COSTS

Ship type	Size	Avg days at sea	Avg Fuel per year ('000 tonnes)	Avg fuel price	Avg fuel cost per day	Idle days inspection and clean	Reduced variable costs
Container	2,000 TEU	208	5.05	275 USD/mt	(5,050 / 208) x 275 = 6,676	7 days	6,676 x 7 = **46,732**
	Ship data	Using list in Annex B, or estimation from ship operator	Using list in Annex B	Data from country or ship operator	(fuel per year / days at sea) x avg fuel price	Assumption	Fuel cost per day x idle days

REDUCED FIXED COSTS

Reduced fixed costs would be mostly related to lower operational costs during idle period related to inspection and mandatory cleaning. The main operational cost item that could be considered would be crew-related costs. However, due to the limited period and absence of advance planning of forced inspection and cleaning, it would be difficult to reduce any of the daily operational costs of a ship.

LOSS OF GROSS PROFIT

In our example:
Loss of gross profit = 666,645 – 46,732 – 0 = 619,913

Example. Calculating economic loss - continued

ADDITIONAL COSTS INCURRED						
Ship type	Size	Idle days inspection and clean	Cost of inspection	Cleaning cost	Other costs	Additional cost incurred
Container	2,000 TEU	7 days	5,000	75,000	50,000	5,000 + 75,000 + 50,000 = **130,000**
	Ship data	Assumption	Price to be determined locally	Price to be determined locally	e.g. Dockside fees and services. Data from country or port	Cost of inspection + Cleaning cost + Other costs
ADDITIONAL INCOME						
The authors could not determine any instances where a ship could generate additional income while docked for inspection or hull cleaning						

OTHER ECONOMIC LOSS

Other Economic loss = Loss of gross profit + Additional costs incurred – Additional income

Other Economic loss (for one ship) = 619,913 + 130,000 – 0 = 749,913

Other Economic loss (for all ships in same ship type and size) = 23 registered ships x 749,913 = **USD 17,247,999**

The notation table can now be updated with the calculations above, as per example below. As suggested earlier, alternative formats are also possible to use, so long the list of vessels is documented.

Example. Economic loss to shipping

Industry or ecosystem	Source of information or reference	Reference value and details	Area of value (where relevant)	Year (of value, not reference)	Industry item or ecosystem service selected	Assessment by MP or VT	Estimated value (calculation)
Shipping	Sourced locally, 2019	Not applicable	Not applicable	2019	Other economic loss	MP	USD 17,247,999

With Policy Scenario

The same calculations conducted for the 'without' scenario may now be repeated assuming that the impact of biofouling will be lower with a biofouling management policy, or by applying an assumed overall reduction in costs to fuel consumption, GHG emissions and other economic costs due to improved biofouling management. Where the introduction of a biofouling management policy is expected to push the industry to adopt improved biofouling management measures and eliminate biofouling, the costs of biofouling with policy will be nil. In other cases, a policy may only lessen costs. In addition, the cost of improved biofouling management measures should be estimated for the industry.

Costs of Improved Biofouling Management

Preventive measures for managing biofouling on ships would consider both the cost related to planning and reporting, the additional cost of an improved anti-fouling system, an MGPS for niche areas and any costs related to monitoring and maintenance.

Planning and reporting

- Biofouling management planning and reporting. Average cost of development and update of a Biofouling Management Plan (BFMP) and Biofouling Record Book (BFRB), based on estimated personnel working hours allocated to biofouling planning and management and for reporting to ports or national jurisdictions.
- Training of personnel dealing with biofouling management, essentially for any ship-based operations and maintenance, such as how to inspect and monitor coating, how to prepare and implement BFMP, how to operate on board inspection technologies.
- Operational costs. Reduced revenue related to idle days during antifouling system application and maintenance.

Antifouling system

- Additional cost of enhanced antifouling system or a MGPS for niche areas. Note: dry-dock, coating/system cost and application would be a cost already borne by the ship owner when applying an existing coating.
- Cost of other preventive or maintenance measures, such as hull grooming, based on the BFMP.
- Monitoring costs: Monitoring and inspection of coating, including personnel working hours and purchase of tools such as small camera systems or drones.

The following examples (see pages 63, 64 and 65) continue with the same case proposed in previous sections, for a country with only 23 registered ships of the same ship type (container) and same size category (all under 2,000 TEU). The calculation is based on one single ship and, therefore, the outcome should be multiplied by the total number of ships under that category of ship type and size. For the scenario under consideration, drydock would occur every 5 years. The number of days that can be allocated to antifouling operations (blasting, hull preparation, coating, curing, etc) would be an average 15 days in total – under the assumption that while the whole operation would take more days, there are other maintenance operations taking place in parallel.

Example. Calculating biofouling management, reporting and training.

BIOFOULING MANAGEMENT PLANNING (per ship)			
Number of People involved	Avg salary per person / day	Planning. Days per year	Cost biofouling planning
1	200	2 days	2 x 200 = **400**
Assumption that a ship operator could allocate up to 2 persons to develop its fleet's BFMPs	Data to be determined locally	Includes review and assumes economies of scale when preparing for a fleet	Number of people x Avg salary per person x days per year

Example. Calculating biofouling management, reporting and training - continued

BIOFOULING MANAGEMENT MONITORING AND REPORTING (per ship)			
Number of People involved	Avg salary per person / day	Reporting. Days per year	Cost of biofouling reporting
1	200	5 days	1 x 200 x 5 = **1,000**
Assumption that one crew member would be taking responsibility to update the BFRB and monitor performance while in port	Data to be determined locally	Includes BFRB and reporting to ports and national jurisdictions	Number of people x Avg salary per person x days per year
BIOFOULING MANAGEMENT TRAINING (per ship)			
Number of People involved	Avg salary per person / day	Cost of training per person (1 day)	Cost of biofouling management training
3	200	600	(3 x 200) + (3 x 600) = **2,400**
The 3 persons fulfilling the two tasks described above	Data to be determined locally	Average price for one-day training courses on most subjects	(Number of people x avg salary per person) + (number of people x daily cost of training)

PLANNING, MONITORING AND TRAINING = Cost of biofouling management planning + Cost of monitoring and reporting + Training costs

In our example: PLANNING, MONITORING AND TRAINING = 800 + 1,000 + 2,400 = 4,200

Extrapolated to the country's fleet used throughout the example: 23 registered ships x 4,200 = **96,600**

Example. Calculating operational costs related to antifouling maintenance.

ANTIFOULING MAINTENANCE (per ship)					
Ship type	Size	Avg days at sea	Price per maintenance clean	Number of cleans per year	Cost of antifouling maintenance
Container	2,000 TEU	208	USD 15,000	2	2 x 15,000 = **30,000**
	Ship data	Using list in Annex A, or estimation from ship operator	Assumption. Price should be determined locally, with an average between diver and ROV-based maintenance.	Assumption	Price per clean x number of annual cleans

Example. Calculating operational costs related to antifouling maintenance - continued

LOSS OF REVENUE (in relation to idle days per ship due to antifouling maintenance)

Ship type	Size	Avg days at sea	Avg TEU per year	Avg freight rate per TEU	Daily revenue per ship	Idle days per year for maintenance	Loss of revenue
Container	2,000 TEU	208	19,809	1,000	(19,809 x 1,000) / 208 = 95,235	2 days	2 x 95,235 = **190,470**
	Ship data	Using list in Annex A, or estimation from ship operator	Based on average voyage times long haul (21 days)	Estimation from ship operator	Avg TEU per year x Avg freight rate / Avg days at sea	Estimation, based on the assumption that 2 days per year can be allocated to maintenance	Number of days at drydock per year x daily revenue per ship

REDUCED VARIABLE COSTS (in relation to idle days per ship due to antifouling maintenance)

Ship type	Size	Avg days at sea	Avg Fuel per year ('000 tonnes)	Avg fuel price	Avg fuel cost per day	Idle days inspection and clean	Reduced variable costs
Container	2,000 TEU	208	5.05	275 USD/ mt	(5,050 / 208) x 275 = 6,676	2 days	6,676 x 2 = **13,352**
	Ship data	Using list in Annex A, or estimation from ship operator	Using list in Annex A	Data from country or ship operator	(fuel per year / days at sea) x avg fuel price	Assumption	Fuel cost per day x idle days

REDUCED FIXED COSTS (in relation to idle days per ship due to antifouling maintenance)

Ship type	Size	Daily operating costs	Idle days inspection and clean	Reduced operating costs	Reduced fixed costs
Container	2,000 TEU	5,172	2 days	20%	(5,172 x 2) x 20% = **2,068**
	Ship data	Data from OpCost	Assumption	Assumption	Daily cost x idle days x % reduction

OPERATIONAL COST = Antifouling maintenance + Loss of revenue – Reduced variable costs – Reduced fixed costs

In our example:

Operational cost = 105,000 + 190,470 – 13,352 – 2,068 = 310,890

Extrapolated to the country's fleet used throughout the example: 23 registered ships x 310,890 = **7,150,470**

Example. CBA of improved biofouling management for a national fleet

Based on the calculations conducted within this section focused for the Shipping industry, the cost-benefit analysis would present the following figures that should be entered in the Calculation tool:

Increased costs due to poor biofouling management	
Additional fuel:	11,800,840
GHG emissions:	813,050
Other economic costs:	18,397,999
Subtotal	**31,011,889**

Cost of improving biofouling management	
Planning, monitoring & training	96,600
Antifouling monitoring & maintenance	7,150,470
Subtotal	**7,247,070**

CBA conclusion: the cost of improving biofouling management across the fleet would reduce OPEX by approximately USD 23 million per year

3.2 Appraising the Ports and Marinas Sector

When considering impacts related to biofouling and IAS, two main impacts affect ports: harm to support vessels and harm to port infrastructure. The focus of estimation for ports will be to calculate the potential economic harm:

- To support vessels and infrastructure without a policy, and
- The potential reduction in economic harm from having one (reduced harm to support vessels and infrastructure).

Table 14 details the main types of information that should be secured during the data gathering step to estimate the costs of economic harm to support vessels and infrastructure, without a policy. For other assets or services, the main source of information, when available, should be the National Status Assessment report for the country. More information on this sector in relation to biofouling may be found in section 2.4.1 of the Guide to Developing National Status Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species, published by GloFouling Partnerships.

Table 14: Data requirements and sources of information for port and marinas

Type of information	Specifications	Sources of information
Ports and marinas	Collect information for commercial ports and recreational marinas operating in the country, including: • Number of ports and marinas (or % of total fleet) likely to be affected • Number of port support vessels likely to be affected • Number of berths or mooring spaces likely to be affected • Annual operations (number of ships) likely to be affected • Average price per category of port services related to biofouling prevention and management • Itemised annual maintenance expenditure in relation to biofouling prevention or management	• National Status Assessment report (if available). • Ports and marina operators • Port authorities • Relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), • Shipping companies. • IMO's ISIS database • UNCTAD Country maritime profile

Table 14: Data requirements and sources of information for port and marinas - continued

Type of information	Specifications	Sources of information
Port-based services	Prevailing prices for: • Hull cleaning and grooming services: prices and service costs will vary considerably from one country to another and should be sourced from local companies offering this type of services. Prices should consider both diver-based and ROV-based services. • Drydock and port fees. Prices and service costs will vary considerably from one country to another and should be sourced at least from within the region. • Antifouling coatings: prices and service costs should be sourced from local dealers and dry-docks or using national websites of main manufacturers or distributors of antifouling coatings.	• Dry docks, manufacturers and service providers available in the country (or, if unavailable, in the region). Ports and marina operators • Port authorities • Relevant line Ministries and agencies (e.g. Transport, Maritime Safety Authority, Trade & Industry etc.), • Shipping companies.
Port infrastructure	Local prices for key port equipment (buoys and other signalling and traffic monitoring equipment and technologies)	• Local ship chandlers • Ports and marina operators • Port authorities

WITHOUT Policy Scenario

The further sections present the main parameters to be considered for calculating the impact of biofouling and IAS in ports and marinas. This is followed by a detailed explanation of each parameter and some examples.

Impact on Port Support Vessels

Assessment of biofouling-related costs and management of port support vessels should follow the same parameters indicated for shipping, depending on their size. The calculation should strive to assess the impacts on one port and then multiply by the number of commercial harbours in the country. Data should be sourced locally, particularly pricing for services and fees.

Impact on Port Infrastructure

For port infrastructure, biofouling may accelerate the deterioration of some of the port assets. Key items to be considered should be:

- Damage to buoys and other signalling and traffic monitoring equipment and technologies (cleaning costs, asset replacement costs).
- Structural damage and corrosion of barges, wharfs, jetties and other mooring structures (cleaning costs, asset repair or replacement costs).
- Ropes and other mooring equipment (cleaning or replacement costs).
- Additional staff costs or services related to biofouling maintenance or cleaning
- Loss of revenue (due to reduced mooring spaces and services)
- Additional or reduced corporate costs due to biofouling operations

Impact on Port Operations

Potentially, the detection of an IAS in a port or marina could trigger the highest economic impact. Efforts for containment and/or eradication of an IAS could require restricted operations of even the closure of a port or marina for a period of time. Key items to be considered are:

- Loss of revenue due to restricted or cancelled operations. Country or Port authorities could dictate cancellation or closure of operations to and from the port, with a significant impact on revenue.

- Compensations. Due to restricted port operations, ship managers or supply chain operators could potentially present claims for delays and/or redirection. If a port does not have a suitable insurance in place, the economic impact of any compensations could be considerable.
- Fines. The Environment Authority of a country could hold the port responsible for inaction to prevent IAS and this could be conductive to fines.

Potential Sources of Income

Sources of income related to provision (or licenses to operate) of biofouling management operations such as antifouling coatings, in-water cleaning or grooming services, biofouling waste management, dry-dock and boat haul for biofouling management and prevention purposes should be included. These values represent gains to the sector, compared to losses arising from biofouling.

Example. Impact of IAS on port structures

A general economic impact of IAS in the Wadden Sea is the intensified need for maintenance of harbour docks. Japanese oysters are much harder to remove than native fouling species such as mussels. In a study conducted by Gittenberger et al. (2011), a comparison was made of the time required to clean an area fouled by mussels with an area fouled by Japanese oysters. The analysis included two floating docks in the harbour of Breskens and on 40 m2 of dike in the Oosterschelde estuary, and it took about five times longer to get rid of oysters than of mussels, scraping with an iron shovel. To assess the extra maintenance cost linked to exotic fouling species along the coast, the study interviewed 56 stakeholders of (mainly pleasure craft) harbours along the Dutch coast. The minimal annual costs directly related to fouling species in these harbours was estimated at € 945,000 of which ~ 22 % (€ 207,000) concerns extra costs related to IAS. Most of these costs concerned boat, scraping & spraying, and scuba-diving costs. Structures that were most costly to keep clean were the oil screens in Rotterdam harbour (screens that can be used to minimize the spread of oil in case of an oil spill), and more in general along the coast the floating docks and the dikes. Although the introduction of the Japanese oyster was intentional for aquaculture purposes in the early 20th century, it has continued to expand its range both by natural means and through fouling of mobile structures. This example reflects how actions taken in one maritime industry can have an impact on other neighbouring maritime sectors and infrastructure.

Example. Impact of IAS on port operations

The detection of a new species in a port that could present a high risk of invasion, could potentially trigger a response in the form of efforts to contain and eliminate the species. Conducting this could motivate the closure of some areas of the port and the reduction of traffic to facilitate eradication and containment.

In March 1999 a massive infestation of black-striped mussel was discovered in Cullen Bay Marina in Darwin. It was fortunate that the incursion took place in a marina with lock gates that when closed isolated the incursion from the waters of Darwin Harbour.

Thanks to a rapid response, the organisms were eradicated from vessels and marina infrastructure in about three weeks. During that time all vessels inside the harbour were quarantined and prevented from moving. The cost of the emergency response in Darwin in 1999 was estimated as being in excess of $3.2 million in 2012 terms. However, this did not include other costs such as idle or layup periods for vessels with planned visits to the Port (Summerson et al, 2013).

WITH Policy Scenario

The same calculations conducted for the 'without' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in costs for hull cleaning, dry dock and port fees and antifouling coatings. Where the introduction of a biofouling policy is expected to eliminate biofouling and IAS, the costs with policy will be nil. In other cases, a policy may only lessen costs. The change in biofouling levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere
- Expert opinion
- List and description of values (where no data exists).

Importantly, income accruing to ports and marinas from biofouling would be expected to fall with the introduction of a biofouling policy. This may make a prospective policy unpopular with some vested interests. Harm to interest groups (e.g., hull cleaning services) from a biofouling policy should be accommodated by:

- estimating potential lower earnings under a 'with' scenario and
- noting these impacts in the socioeconomic analysis (see Step 7).

Costs of biofouling management

When considering the costs of managing biofouling in ports, the key parameters to be considered are related to planning, asset monitoring and maintenance, for example:

- Antifouling costs and maintenance of barges and support vessels. Include cost and application of antifouling system and monitoring and inspection.
- Maintenance of signalling and traffic monitoring structures.
- Maintenance of wharfs, jetties and other mooring structures.
- Monitoring and inspection of surfaces and coatings, including time of personnel and purchase of tools such as small camera systems or drones.
- Training and administration costs of port personnel.
- Loss of revenue due to asset maintenance

3.3 Appraising the Aquaculture Sector

Biofouling is considered as one of the main barriers to efficient and sustainable production in aquaculture. The direct economic costs of managing biofouling are estimated to be 5–10% of production costs (Lane et al, 2004), but this may be very different according to stock species, geographical location and biofouling management practices. In fact, the overall cost is likely to be underestimated, due to differences in cost accounting and that indirect impacts are often not being valued.

The impact of Invasive Aquatic Species is strongly linked to biofouling. In fact, aquaculture production sites use a wide range of materials (plastics, metals, etc) in various forms (nets, cages, buoys, trays, etc), that biofouling affects differently. In addition, small-scale and/or non-industrial production units, scattered over ample regions, are prevalent in many countries, making it difficult to obtain detailed information. As a result, it can be difficult to estimate the impact of biofouling on a diverse aquaculture industry, so calculations for the aquaculture industry in developing countries may require making extrapolations based on a limited dataset.

The focus of estimation for the aquaculture sector will be to calculate the potential economic harm to production (yields) and operating costs.

WITHOUT Policy Scenario

Table 15 details the main types of information that should be secured during the data gathering step. The information listed in the data sources will not always be clear about the methodologies applied for calculating the value/prices. One major issue is whether the costs for capturing fish (like wages, equipment) are included in the values/prices, or not. Also, subsidies and taxes create distortions of the economic value, or raise questions as to whether the price actually reflects the "real value", etc. These issues are important, but also very complex to solve. In the context of developing calculations for the economic assessment, time and resources should not be wasted getting into these issues. Instead, the analysts should (i) note what information is acquired from the source about these issues (ii) document in the validation step of the analysis (Chapter 2) what is included, what is not, and where things are just unknown. More information on this sector in relation to biofouling may be found in section 2.4.3 of the Guide to Developing National Status Assessments of Biofouling Management to Minimize the Introduction of Invasive Aquatic Species, published by GloFouling Partnerships.

The main guidance for securing information, when available, should be the National Status Assessment report for the country and section 3.3 of the NSA Guide published by GloFouling Partnerships. Special care should be taken not to include data from aquaculture in land-based systems. Auxiliary vessels in the aquaculture industry should be considered in this section using the same method.

Table 15: Data requirements and sources of information for the aquaculture industry

Type of information	Specifications	Sources of information
Aquaculture sector characteristics	Collect information on aquaculture farms operating in the country, including: • Number of aquaculture farms or % of total farm sector likely to be affected, classified by type (Freshwater or mariculture; Stock: finfish, algae, shrimp, or molluscs), size. • Annual production by type of farm • Annual OPEX by type of farm • Avg number of support vessels used per enterprise. • Itemised annual maintenance expenditure in relation to biofouling prevention or management	• National Status Assessment report (if available). • Reports and databases from relevant line Ministries and agencies (e.g. Fisheries, Environment, Trade, etc.) • Aquaculture companies and industry associations. • The Regional Fisheries Bodies (RFB) • The Fisheries and Resources Monitoring System (FIRMS) • FAO Fisheries and Aquaculture Statistical Yearbook • FAO Fisheries and Aquaculture Department • NOAA Fisheries • EU Data collection
IAS	• Studies relating to IAS and their impact on aquaculture farming in the country or region	• Scientific research institutions or universities • Aquaculture companies and industry associations. • Relevant line Ministries and agencies (e.g. Fisheries, Environment, Biosecurity, etc.).

Table 15: Data requirements and sources of information for the aquaculture industry - continued

Type of information	Specifications	Sources of information
Services	Local prices for cleaning services and equipment (buoys, pens, nets, etc)	• Manufacturers and service providers available in the country (or, if unavailable, in the region). • Relevant line Ministries and agencies (e.g. Fisheries, Environment, etc.) and Research institutions or universities • Aquaculture companies • Ports

The impacts on aquaculture of biofouling and IAS can be divided into two key aspects: Impact on production (stock species) and Impact on infrastructure. The further sections present the main parameters to be considered for calculating the impact of biofouling and IAS on the aquaculture industry.

Box 10: How to estimate the cost of biofouling and IAS on the aquaculture sector

Due to the high variety of types of stock species and farm sizes, a very general method common method for estimating the cost would be based on estimating the value for an average farm representative of the sizes prevailing in the country and then apply it to the total number of farms. The calculation should be based on the following:

Total cost = Impact on production + Impact on infrastructure

Impact on production = $\sum (F_T \times P) - B$

Impact on infrastructure = $\sum F_T \times (M + I_C)$

Where:

F_T - Number of farms broadly divided into types (aquaculture and stock type and enterprise sizes)

P – Cost of impact on production (lost or damaged stock species, additional production costs)

B – Benefits derived from biofouling (or IAS)

M – Additional infrastructure maintenance costs

I_C – Intermediate costs (or replacement costs of intermediate goods that are used in the production of final consumption goods. For example, the cost of fishing gear used to harvest fish)

Impact on Production

Without a policy, operational costs can be expected to increase, and or revenues can be expected to fall as a result of:

- Occlusion of pen nets. Reduced water flows through nets and trays due to biofouling often result in reduced food supply, waste removal and dissolved oxygen being available for the cultured stock, degrading water quality and impacting its growth rate or even its survival. Net occlusion also increases drag forces on the net, adding strain to mooring systems and deforming the pen net, effectively reducing its volume by up to 40%..
- Biofouling leads to a need for more frequent cleaning, net replacement and/or application of antifouling products. This can increase the stress on cultured fish, reducing growth rates and productivity. In addition, release of gametes during net cleaning operations without waste collection can facilitate their further expansion.
- The introduction of diseases and parasites could be another consequence of biofouling that may lead to production losses.

The effect is:
- higher operational costs as a result of wasted feed stock, increased pen monitoring and maintenance and increased cleaning needs, and
- potential losses in revenue as a result of species stock damage or loss.

Box 11: The European Green Crab

In 1938, New England fishermen brought in 14.5 million pounds of the soft-shelled clam Mya arenaria. By 1959, that number had dropped to just 2.3 million, due to the introduction of the Green Crab *(Carcinus Maenas)*, a highly adaptable and voracious predator that almost wiped out the soft clam industry in Maine in the 1950s. Green crabs can also move to eat eelgrass deeper in the water, which is an important habitat for many juvenile fish, and they feed on young oysters, clams, mussels, and other shellfish commonly found in eelgrass. In Tomales Bay, California, research linked a decline in up to 40% of Manila clam harvest due to the green crab establishment. In contrast to the species they feed on, the green crab has no significant commercial value because they are small (less than 4 inches wide), and don't yield much meat.

According to Carlton and Cohen (2003), green crabs may travel via modern-day ship fouling — by attaching to the interior of vessel seawater pipes. Another possible vector is the fouling of exploratory drilling platforms (Carlton and Cohen, 2003).

The estimated total losses from green crab predation to commercial and recreational shellfisheries on the US East Coast and eelgrass restoration efforts range from $18.6 to $22.6 million per year. Although losses to West Coast fisheries are currently negligible, they have the potential to increase to $844,000 per year (Lovell et al. 2007). In contrast, the United States government spent only about $315,000 between 2007–2010 to manage the green crab problem (US EPA, 2008).

Stock damage may result in a fall in market price. In shellfish farming the physical damage of fouling organisms that bore into the shell or grow on the shell surface, which can affect the aesthetics of the product. Options may be available for reducing damage, normally by cleaning, but this would also represent additional labour (production) costs.

The effect of biofouling on aquaculture pond aeration devices raises the cost of production through electricity consumption, increased maintenance cost and labour cost. For example, when heavily fouled, the current drawn by paddle wheels has been estimated to be up to 50% greater. It has been estimated by one farm that, on average, power consumption was increased by 20% and 50% extra maintenance and repair cost due to biofouling.

The two following examples present two different methods for calculating the impact of IAS on stock species.

Example. Calculating the impact of biofouling by an IAS on oyster production (direct method)

Oyster production has been impacted by biofouling related to a tubeworm (Ficopomatus) invasion in Country X. Biofouling impairs growth of oysters, with direct consequences relates to size and potential market price of production. The lack of cleaning of the oysters causes not only the proliferation of Polidoras that pierce the shells causing the death of organisms, but also gets inside the shells causing their decline. Cost of cleaning in Country X has been identified as approximately USD 50 per sack of 200 oysters (approximately USD 3 per kilogram).

Considering that annual oyster production in Country X for 2019 was 1,300 tones.

Additional production costs for industry = 1,300 tonnes x USD 3 per kg = USD 3,900,000

Example. Calculating impact of IAS on aquaculture (Case transfer method)

This example uses the value transfer method to estimate a potential impact of IAS on the aquaculture industry in a developing country X, where no information is available at the national level.

Using the list of EV studies, we identify a case in New Zealand that estimated the impact of the tunicate Styela clava on the production of green lipped mussel farms over a 24-year period. The impact represented an estimated 4% of the total industry revenue.

The case is selected because country X does have a shellfish aquaculture industry, estimated at USD 200 million per year. There are several underlying assumptions when transferring the case of the New Zealand study that should be noted when transferring to country X: 1) the study New Zealand focuses on one species, whereas the shellfish aquaculture industry of country X could be focused on other types of mussels or shellfish; 2) the study analysis the impact ion revenue, but does not indicate profit margins.; 3) Styela clava has not been identified in country X, but its presence has been detected in the region (or there is confirmation of ongoing trade between a port in country X and another country where Styela clava is present.

Assuming that the case can still be adapted to country X with acceptable levels of uncertainty, the potential impact of this IAS could be: USD 200 million x 4% = USD 8 million.

This result would need to be adjusted based on price levels and adapted to present day value.

Impact on Infrastructure

For the impact of biofouling on vessels supporting the aquaculture industry, the general method presented in 3.1 for shipping should be applied.

While the surface area of fouling is important in aquaculture production - in terms of reduced water flow rates through nets and trays - the weight of the fouling organisms and communities is also a major factor contributing to the overall impact of biofouling on production and especially on the material and equipment. This may entail the following issues:

- Increased expenditure on infrastructure, due to structural damage and/or accelerated fatigue, includes replacement of pens, cages, etc.
- Damage to other tools and structure (e.g. replacement of ropes, nets)
- Other economic costs, including loss of revenue due to limited operations related to biofouling cleaning or structure replacement.

Hydroids on a net sample

Box 12: Cost of aquaculture pen replacement

The replacement of nets for aquaculture farms is expensive. For example, annual costs to replace nets and reapply antifouling for a medium-sized UK salmon farm is estimated to be ±€ 120.000. Based on this, under the assumption that one net would need to be replaced every year in all finfish aquaculture farms in the UK and that approximately there are 257 salmon marine aquaculture sites (2012), the annual cost would be 120,000 x 257 = Euro 31 million

However, to assess a potential impact attributable to an IAS linked to biofouling, it would be necessary to determine that the species has created a noticeable increase in the replacement rate of pens. This information should be determined through data or information gathered directly from industry associations or directly from farm managers.

WITH Policy Scenario

The same calculations conducted for the 'with' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in the economic production value of the sector. Where the introduction of a biofouling policy is expected to eliminate biofouling and IAS, the costs to the aquaculture sector with policy will be nil. In other cases, a policy may only lessen costs. The change in biofouling levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere

- Expert opinion
- List and description of values (where no data exists)

Costs of biofouling management

Removal of biofouling on pen nets in the aquaculture industry is mainly implemented using in situ net cleaning technology that relies on pressurised water expelled from rotating discs mounted onto a cleaning rig that moves along the inside of pens and washes biofouling organisms off the nets. However, as briefly discussed earlier, this can impact in several ways the stock species, particularly in finfish farms.

Therefore, when considering the costs of improving biofouling management for aquaculture, new techniques and investments would need to be taken into account. Key parameters to be considered are:

- Cost related to improved biofouling management planning
- Costs related to new biofouling prevention strategies and technologies: Cleaning with waste collection; use of double-nets; enhanced rope and cage cleaning; spatial; combination of stock species and other natural control methods; etc. Some of these approaches have limited uptake and barriers also exist when investment is required from small scale producers.
- Antifouling costs and maintenance of support vessels, including, cost and application of antifouling system and maintenance.

The cost is likely to be different for each type of aquaculture farm and therefore, an approximate calculation should be conducted for each type, based on data secured at the national level, and then extrapolated to the total number for farms in the same category.

Box 13: The cost of biofouling management for aquaculture farms

A recent study conducted in Norway on the combined total cost of traditional biofouling prevention and management established an estimated cost of US$ 420,000-493,000 (2020) per farm and production cycle using technologies typically applied in the industry. Considering that current prevention and management strategies are many times short-lived and may impact stock species increase biofouling waste release.

New approaches for biofouling management in this sector are likely to focus on alternatives such as the use of novel technologies for cleaning and waste collection (allowing proactive cleaning without damaging stock species), more effective coatings specifically designed for the aquaculture industry with limited uses of biocides, etc. The main objective will be in longer lifespan of materials and infrastructure and reduced production loss (number or quality of stock species).

However, at the time of writing, there are no studies quantifying the benefits of new approaches for the aquaculture sector. Therefore estimating developing a CBA for improved biofouling prevention and management measures will be difficult.

3.4 Appraising the Fishing Sector

Although the commercial fishing industry is fundamentally a ship-based sector, it should be treated separately to understand the specific impacts that biofouling and/or IAS may have on its production and infrastructure. An important consideration when assessing this sector is to differentiate between large or mid-size fishing vessels and the smaller artisanal fishing (or traditional/subsistence fishing), which entails various small-scale, low-technology, low-capital, fishing practices undertaken by individual fishing households (as opposed to commercial companies). Many of these households are of coastal or island ethnic groups with limited investment opportunities.

For this reason, the information generally available on this sector will not always be clear about the methodologies applied for calculating the value/prices. One major issue is whether the costs for capturing fish (like wages, fuel, equipment) is included in the values/prices, or not. Also, and as in other sectors, subsidies and taxes may create distortions of the economic value. These issues are important, but also very complex to solve. In the context this study, time and resources should not be wasted getting into these issues. Instead, note whatever information you acquire from the source about these issues, and make clear to the reader what is included, what is not included, and where you just do not know how the values stated have been calculated.

The focus of estimation for the fishing industry sector will be to calculate the potential economic harm to production (yields) and operating costs.

Table 16 details the main types of information that should be secured during the data gathering step. As for other industries, the main guidance for securing information, when available, should be the National Status Assessment report for the country and section 3.3 of the Guide for NSA published by GloFouling Partnerships. Special care should be taken not to include data from the aquaculture sector. More information on this sector in relation to biofouling may be found in section 2.4.3 of the NSA Guide, published by GloFouling Partnerships.

Table 16: Data requirements and sources of information for the fishing industry

Type of information	Specifications	Sources of information

Fishing sector characteristics	Collect information on the fishing sector operating in the country, including:
	• Number of ships or % of fleet likely to be affected, roughly divided in three sizes, taking into consideration two different fleet components:
	  o Registered fleet: vessels registered in the country, regardless of whether they are actively trading in the country or not.
	  o Domestic fleet: vessels servicing the country's domestic transport demand by moving goods and people from one port of the country to another port of the country.
	• Annual production by type of fishing vessels and main type of fishing
	• Annual OPEX by type of fisheries
	• Avg number of support vessels used enterprise.
	• Itemised annual maintenance expenditure in relation to biofouling prevention or management
		• National Status Assessment report (if available).
		• Reports and databases from relevant line Ministries and agencies (e.g. Fisheries, Environment, Trade, etc.)
		• Fishing companies and reports from industry associations
		• The Regional Fisheries Bodies (RFB)
		• The Fisheries and Resources Monitoring System (FIRMS)
		• FAO Fisheries and Aquaculture Statistical Yearbook
		• FAO Fisheries and Aquaculture Department
		• NOAA Fisheries
		• EU Data collection

IAS	• Studies relating to IAS and their impact on fisheries and nursery grounds mortality in the country or region	• Scientific research institutions or universities • Fishing companies and industry associations. • Relevant line Ministries and agencies (e.g. Fisheries, Environment, Biosecurity, etc.).
Services	Local prices for cleaning services and equipment (buoys, pens, nets, etc)	• Manufacturers and service providers available in the country (or, if unavailable, in the region). • Relevant line Ministries and agencies (e.g. Fisheries, Environment, etc.) and Research institutions or universities • Fishing companies • Ports

Box 14: How to estimate the cost of biofouling and IAS in the fishing sector

The calculation should be based on the following:

Total cost = Impact on infrastructure + Impact on landings

Impact on infrastructure = *S x (F + G + M)*

Impact on landings = *L x R*

Where:

S - Number of fishing vessels

F – Increased fuel consumption due to biofouling per ship

G – Cost of additional GHG emissions per ship

M – Additional infrastructure maintenance costs per ship (or replacement costs of intermediate goods that are used in the production of final consumption goods. For example, the cost of fishing gear used to harvest fish)

L – Estimated value of annual landings for each fish category

R – % reduction of landings

Although fishing vessels come in a wide range of types and sizes, they can be generally divided into two main categories: large-medium sized vessels and small-sized artisanal vessels. Smaller scale fishing practices normally represent the bulk of the of the fishing fleet in developing countries. However, and due to the limited resources available to coastal communities whose livelihoods may depend on this type of fishing, biofouling prevention practices may be limited and are commonly reduced to increasing communication and awareness of the issue and ensuring that the antifouling systems applied are environmentally friendly and as effective as possible. Although in some extreme cases, small-sized fishing vessels may act as pathways for regional expansion, this may be more limited role, at least for the more artisanal fishermen that rarely go beyond their established operating areas. Therefore, calculations on the impact of fuel consumption and GHG emissions of fishing vessels should be focused one single category that includes large and medium sized ships.

Without Policy Scenario

The impacts of biofouling and IAS on the fishing industry be divided into two key aspects: Impact on infrastructure and Impact on landings. The further sections present the main parameters to be considered when assessing the cost of bot items.

Impact on Infrastructure

Calculating the economic impact of biofouling and IAS on infrastructure related to the fisheries industry should focus on two key aspects:

- Increased hull roughness due to biofouling. Estimation of economic costs should follow the same method as presented in section 3.1 to calculate the cost of increased fuel consumption and additional GHG emissions.
- Other economic costs. This category would include additional cleaning or replacement costs due to IAS on tools used in the fishing industry, such as nets, cages and ropes.

The existence of a shipping industry in the country will mean that all services and tools should be locally available. Therefore, calculations should be based on local prices sourced from local service providers and/or chandlers.

Impact on Landings/Catches

The volume and market value of landings from the shipping industry may be affected both by fouling IAS, which may be the trigger for reduced landings, due to either limited fish stocks or impairment of fishing tools (loss of effectiveness).

In all cases, to avoid the impact of market fluctuations due to changes in supply and demand of a specific product, calculations should be based on comparing the volume of landings. Any difference in the volume of landings

Box 15: Impact of IAS on fisheries

Rugulopteryx okamurae is an invasive algae that has recently appeared of both sides of the Strait of Gibraltar. Initial introduction is not certain, but both ballast water and hull fouling are suspect. R.okamurae is a heavy fouler along the coast, and its expansion suggests that growth is not only fueled by land-based runoff, but local and recreational boating could be playing a role in expanding its reach.

The algae affects the artisanal and trawler fleets. Not only they don't bring in any fish, but gear cleaning takes a long time and is very expensive. One fishing gear is about 1,500 euros (about 750 metres of nets and each boat, depending on its capacity, has between three and five gears).

In the port of Conil the seaweed occupies 70 percent of the fishing grounds. The downward progression of fishing reflects the impact. For example in 2014 local fishermen collected 112,000 kilos of voracious fish (Pagellus bogaraveo) and in 2021 only 8,000.

First to raise the alarm were the fishermen of Algeciras and Tarifa who use the trammel net. They go out fishing and what they collect are kilos and kilos of seaweed that clings to the net and in some cases makes it impossible to pull them back to the boat, which has led on some

occasions to cutting the ropes and releasing to the seabed. In addition to the environmental damage caused by letting a net fall to the seabed, the fishermen who use this system of fishing or bottom longlining need to buy a new set of nets, which adds more costs to the losses they have been suffering for almost two years and which are added to the purchase of bait, diesel, ice, social security, fish market and sales expenses. This situation is gradually leading the fishermen to ruin. The main skipper of the Barbate Fishermen's Guild estimated that boats using trammel nets or bottom longlines are losing more than 500 euros a day.

The regional government recently approved a total of 2.5 million euros as compensation for the local industry.

should then be priced using a common reference year. In addition, this calculation should also include loss of revenue due to limited operations related to IAS hull or tool cleaning.

With Policy Scenario

The same calculations conducted for the 'with' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in revenue, if appropriate data (e.g., case study examples) can be found. Where the introduction of a biofouling policy is expected to eliminate harm, the costs with policy will be nil. In other cases, a policy may only lessen costs. The change in harm levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere
- Expert opinion
- List and description of values (where no data exists)

Costs of biofouling management

Preventive measures for managing biofouling on fishing vessels would generally follow the same recommendations as for the shipping industry, as explained in section 3.1. This should include the cost related to planning and reporting, the cost of updating and monitoring an existing antifouling system and its monitoring and maintenance. However, some differences may have to be considered taking into account the generally smaller size of fishing vessels and the limited operating areas (although this would not be applicable for large transoceanic fishing and processing vessels).

In many ports, the fishing vessels are normally integrated into well organised associations or cooperatives that allow for sharing common resources. This would entail, for example that costs related to hull maintenance and monitoring tools could be shared within a fleet based at the same port. Therefore, when considering costs along the lines explained in section 3.1, the calculation may consider spreading cost along ports of operations, instead of ascribing it to each vessel.

For smaller scale fishing practices, which normally represent the bulk of the of the fishing fleet in developing countries, due to the limited resources available to coastal communities whose livelihoods may depend on this type of fishing, biofouling prevention practices may be limited and are commonly reduced to increasing communication and awareness of the issue and ensuring that the antifouling systems applied are environmentally friendly and as effective as possible. Although in some extreme cases, small-sized fishing vessels may act as pathways for regional expansion, this may be more limited role, at least for the more artisanal fishermen that rarely go beyond their established operating areas.

3.5 Appraising the Marine Renewable Energies Sector

Marine renewable energies are an emerging sector which is expected to expand exponentially in the next 10 years (OECD, 2016) related to the global move away from carbon-based energy sources. There are many types of structures that take the form of large buoys or barges (wave), submerged turbines (wave and tidal) and floating structures (wind and solar). Biofouling on these structures poses many problems, such as increased roughness and weight impacting drag and energy capture efficiency, with hydrodynamic consequences; accelerated corrosion of components; and compromising sensor accuracy to assess performance. More importantly all structures create new surfaces that could become colonised by non-indigenous species and become a steppingstone for further introduction of IAS into a region. More information on this sector in relation to biofouling may be found in section 2.4.4 of the NSA Guide published by GloFouling Partnerships.

Without Policy Scenario

The chances of success for ocean energy concepts depend to a high degree on their ability to minimize operational risks and prolong service periods without costly maintenance stops. Biofouling can harm the sector by significantly increasing the weight of floating structures and increasing the drag resistance of moving parts such as e.g. tidal turbine blades. Production can also be impaired due to idle periods for replacement of sensors or other unprogrammed maintenance. Therefore, the focus of estimation for the marine renewable energies sector related to biofouling principally concerns revenue loss due to:

- efficiency loss, and or
- Down time.

The relative novelty of the marine renewable energies sector means that there are relatively few case studies presently available to draw on to determine the costs to the sector of biofouling and associated IAS. Simple examples of costs estimated are provided in Example: Impact of biofouling on energy production and an approach to estimate values is provided in the **Box 17** (see next page), where the effects of biofouling are estimated in terms of expected percentage increases in operational (e.g., power) costs. Based on this, possible types of information that might be targeted to assess the effects of biofouling and associated IAS on the sector are provided in **Table 14** (see page 66).

Alternatively – where data is extremely scarce – analysts may apply hypothetical changes in biofouling costs to the sector as a means to explore the level of change would be necessary to enable a biofouling policy to break even (cover its costs). For example, if the costs of a biofouling policy over 20 years is $ 5 million, the policy would need to generate a reduction in costs of that to be viable – equivalent nominally to saving an average of $ 0.25 million each year. If industry costs are in the order of – say - $ 30 million a year, that implies that the policy could be economically viable (breakeven) provided experts believe that costs could be reduced by 8 per cent per year. This approach requires the analyst to discuss the likelihood of such a reduction with industry experts.

With Policy Scenario

The same calculations conducted for the 'with' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in revenue, if appropriate data (e.g., case study examples) can be found. Where the introduction of a biofouling policy is expected to eliminate harm, the costs with policy will be nil. In other cases, a policy may only lessen costs. The change in harm levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere
- Expert opinion
- List and description of values (where no data exists)

Box 16: Impact of biofouling on Wave Energy Converters (WEC)

Energy performance analyses and stress-based fatigue calculations show that, for a Wave Energy Converters (WEC) system which has been deployed for 25 years, biofouling can reduce the total power absorption by up to 10%.

In another, more detailed study of tidal energy turbines, simulated power loss throughout five years of exposure of a tidal turbine due to progressive fouling settlement for different coatings systems. The cost of the estimated effect of increased drag on turbine efficiency could be extrapolated to 221 million Euros over 5 years for a hypothetical 600 MW farm.

Table 17: Data requirements and sources of information for the marine renewable energies sector

Type of information	Specifications	Sources of information
Energy sector characteristics	Type of installation used and total asset replacement cost Number of installations Average production levels and values per year Average annual operating costs including maintenance and repair costs	National or international documents/ research, Case studies from elsewhere Expert opinion on the extra maintenance and repair costs required as a result of biofouling and associated IAS

Box 17: How to estimate the cost of biofouling and IAS in the marine renewable energy sector

Due to the high variety of operations and structures, a very general method for estimating the cost of biofouling management would be based on applying state of the art approaches already applied in other industries. The calculation of potential economic costs should be based on the following:

Reduced gross profit = Lost revenue - Reduced variable costs - Reduced fixed costs

Economic cost = Reduced gross profit + Additional costs incurred - Additional income from new operations.

Where

Lost revenue related to biofouling can be due to:

- Altered hydrodynamic properties of the structure reducing its energy generation efficiency.
- Reduced operational days due to biofouling-related maintenance (e.g. at dry dock or on board a support vessel).

Reduced variable costs would be related to regular operations (such as staff expenditure related to production or external support costs).

Reduced fixed costs would primarily be any staff costs not related to production.

At the time of writing and due to the infancy of this industry it is difficult to identify potential additional costs (other than increased the cost of servicing financial arrangements) or additional income not related to general operations that may be impacted by biofouling. However, both items should be taken into consideration during the information-gathering step for this sector at the national level.

Example. Estimating the impact of biofouling on WEC structures using a case transfer

This example assumes that Country X has plans to deploy WEC structures along two suitable areas along its coastline. The expected joint power output capacity would be 50 GW per year. Taking into consideration that the price per MW is USD50, a simple estimate would value the annual output at: 50 GW x 1,000 x USD 50 = USD 2,500,000 per year.

Assuming that, over its lifetime, the WEC plant could lose 10% capacity due to limited absorption, the cost of unmanaged biofouling would be approximately USD 250,000 per year.

Example. Estimating the benefits of improved biofouling management in WEC structures

The study on tidal energy turbines mentioned in Box 16 (see page 79), analysed the impact of different coatings on biofouling prevention and turbine efficiency. For a hypothetical 600 MW farm, this resulted in staggering differences of Euro 175 million over 5 years between one coating or another – roughly a 380% loss in revenue.

Adjusting power outputs and prices, this example can be applied to make rough estimations of improved biofouling management in development plans for marine renewable energy installations.

3.6 Appraising Offshore Mining Sector

The impacts of biofouling in the offshore mining industry can be difficult to estimate due to the very different types of operations related to the operational stages in the production lifecycle, which may include different vessels or structures for seismic surveys, exploratory drilling, production and closure. Offshore oil and gas structures such as Mobile Offshore Drilling Units (MODUs), Floating Production, Storage and Offloading units (FPSOs) and Floating Liquefied Natural Gas facilities (FLNGs), are large complex artificial surfaces that are frequently coated with paints compliant with IMO's AFS Convention (International Convention on the Control of Harmful Anti-fouling Systems on Ships) and are generally towed slowly between locations. When not managed to control biofouling, such facilities represent a very high risk of transferring IAS into new regions when towed into coastal waters. Furthermore, once in position at an offshore location such structures can also serve as a source of infection for domestic conveyances which may interact with the structure and subsequently transfer IAS to adjacent coastal regions. More information on this sector in relation to biofouling may be found in sections 2.3.2 and 2.4.2 of the NSA Guide published by GloFouling Partnerships.

The consequences of the different types of operations and structures is that biofouling prevention and management needs to be approached from very different perspectives adjusted to the specific needs of each unit or operation. For example, slow moving vessels or specialist vessels for mining exploration and survey, or seabed dredging, may require alternative antifouling methods, as they remain almost static during operations and are prone to increased levels of biofouling before moving to another area. On the other hand,
MODUs and offshore platforms may remain at sea for a large number of years, where the only concern related to biofouling is potentially accelerating corrosion and impairment of drilling tools and sensors. However, operations may be particularly affected when either the unit needs to be towed to a port facility for repairs or when it reaches the end of its operational life. In all cases, a proactive biofouling management approach may significantly reduce the operational costs and/or the limited options for structural repairs.

Relatively few case studies are presently available to draw on to determine the costs to the sector of biofouling and associated IAS. A simple example of possible estimation is provided in the **Box 18** (see next page), based upon which possible types of information that might be targeted to assess the effects of biofouling and associated IAS on the sector are provided in **Table 18**.

Without Policy Scenario

The **Box 18** illustrates that the magnitude of costs of biofouling and associated IAS on the offshore mining sector might be estimated based on a proportion of operational costs for the sector. Where national data exists, this information should be used to determine existing harm to facilities and costs.

Table 18: Data requirements and sources of information for the offshore mining sector

Type of information	Specifications	Sources of information
Offshore sector characteristics	Type of installation used and total asset replacement cost. Number of installations. Average production levels and values per year. Average annual operating costs including maintenance and repair costs and transportation costs.	National or international documents/ research. Case studies from elsewhere. Expert opinion on the extra maintenance and repair costs required as a result of biofouling and associated IAS.

Box 18: How to estimate the cost of biofouling and IAS in the offshore mining industry

Estimating the impact of biofouling and IAS for the offshore mining industry will need to be adjusted to different characteristics or requirements of operations and structures. At the country level, the calculation should be based on the following:

Total cost = Impact on infrastructure + Impact on production + Impact on transport

Impact on infrastructure

Impact on infrastructure = $\sum S_T \times (M + I_C - B)$

Where: S_T - *Number of structures broadly divided into categories related to type and size*

M – Additional infrastructure maintenance costs related to biofouling (including operational or end-of-life)

I_C *– Intermediate costs (or replacement costs of intermediate goods that are used in production)*

B – Benefits derived from biofouling and/or IAS

Impact on production and operations

Impact on production = $\sum S_T \times (P + I_C - B)$

Where: S_T - *Number of structures broadly divided into categories related to type and size*

P – Reduced production output or increased production costs due to biofouling and/or IAS

R – Other economic costs (or replacement costs of intermediate goods that are used in production)

Impact on transport

Impact on transport = Increased fuel costs + Additional GHG emissions + Other economic cost

The calculation should follow the same indications as provided for the shipping industry in further above in this Chapter.

Impact on Infrastructure

Calculating the economic impact of biofouling and IAS on infrastructure related to the offshore mining industry should focus on two key aspects:

- Increased hull roughness due to biofouling. Estimation of economic costs should follow the same method as presented in section 3.1 to calculate the cost of increased fuel consumption and additional GHG emissions.
- Other economic costs. This category would include cleaning costs or replacement of other tools used in the offshore mining industry. Additionally, this calculation should also include loss of revenue due to limited operations related to hull or tool cleaning. The existence of a shipping industry in the country would mean that all services and props will be available in the and should be costed solely using local prices sourced from local service providers and chandlers.

Box 19: Impact of biofouling on infrastructure

Structural damage on an offshore oil rig, created the need to toe it to a shipyard for repairs. However, after inspecting biofouling accumulated in the submersible sections of the rig, authorities prevented the move unless steps were taken to maintain biosecurity in the coastal area where the ship was expected to arrive.

These requirements created the need to hire a specialised ship to lift and transport the oil rig in an environmentally secure manner. The cost of this type of ships is approximately USD 250,000 per day and the operation required 7 days to complete.

The overall cost of the operation was USD 1,750,000

Impact on Production

Calculating the economic impact of biofouling and IAS on production related to the offshore mining industry should focus on two key aspects:

- Reduced operational days due to biofouling-related maintenance (e.g. at dry dock or on board a support vessel).
- Reduced operational days due to maintenance operations not related to biofouling but delayed due to existing levels of biofouling (for example, structure cannot be towed to port due to environmental regulations).

Additional costs incurred. Additional dismantling costs at end of service. Structural damage in relation to increased corrosion levels due to biofouling or damage to sensors and drilling equipment.

Additional income from new operations could be related to conversion of old platforms into nature reserves for recreational diving.

Example. Impact of biofouling on oil & gas production

In December 2007, a semisubmersible was preparing to move to Australia from a foreign country when authorities requested an inspection to detect any IAS. The inspection detected an infestation of green-lipped mussels – a species considered as a high-risk invasive in Australia.

To remove mussels from the rig out at sea, divers and blasters were brought in, with an additional and last-minute expense of AUD 5 million in cost overruns for the quarter. An additional was the loss of revenue from the rig being out of commission for 23 days – with a day rate in estimated at AUD 370,000.

With Policy Scenario

The same calculations conducted for the 'with' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in revenue, if appropriate data (e.g., case study examples) can be found. Where the introduction of a biofouling policy is expected to eliminate harm, the costs with policy will be nil. In other cases, a policy may only lessen costs. The change in harm levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere
- Expert opinion
- List and description of values (where no data exists)

3.7 Appraising the Recreational Boating Sector

There is clear scientific evidence that biofouling on immersed areas of recreational vessels can and does facilitate the translocation of non-native species between bodies of water and along coastlines, and that they can become Invasive Aquatic Species (IAS). Recreational craft can start to collect biofouling on their hulls within hours of being in the water. Dry-sailed craft, such as trailered boats, dry-stacked craft or portable craft rely on dry storage to avoid the accumulation of biofouling on the hulls, whereas vessels that stay afloat will have some form of anti-fouling coating as protection. The hull is the obvious area where biofouling is seen, and therefore cleaned.

There are many other areas on vessels and equipment where biofouling can occur, and therefore be a source of transporting IAS, particularly if they are not readily visible or known areas on a boat, such as bilges, lockers or cooling systems. These so-called niche areas are therefore a key point to consider for biosecurity when moving a boat from one area to another.

The immediate impact of biofouling on recreational vessels is generally known to boat owners. It slows the boat, increasing fuel costs for powerboats, and increasing passage time for sailing boats, who may revert to using the engine sooner, leading to greater engine maintenance demands, potential days fishing lost (important for recreational charter companies), not to mention higher air pollution.

Anti-fouling systems are the main tool to prevent biofouling of immersed areas of pleasure craft. Therefore, the selection and correct application / installation of an effective anti-fouling system is key to biofouling management and preservation of biodiversity in marine environments.

At present, biocidal anti-fouling coatings are the dominant system used. Other options are available to the wider public, and these include non-biocidal surface effect (non-stick) coatings, devices such as ultrasound systems, mechanical cleaning and several other technologies or systems that are under development, although for some of the latter further research is required to assess their efficacy and impact on the environment.

Without Policy Scenario

Table 19 details the main types of information that should be secured during the data gathering step. As for other industries, the main guidance for securing information, when available, should be the National Status Assessment report for the country and section 3.3 of the Guide for NSA published by GloFouling Partnerships.

Table 19: Data requirements and sources of information for the recreational boating sector

Type of information	Specifications	Sources of information
Recreational boating sector characteristics	Collect information on the recreational sector in the country, including: • Number of vessels or % of fleet likely to be affected, roughly divided in three sizes, taking into consideration the main differences (sail or motor vessels, boat length categories).	• National Status Assessment report (if available). • Reports and databases from relevant line Ministries and agencies (e.g. Maritime Authority.) • Reports from Marinas or Boating associations
Hull cleaning costs	• Hull cleaning and grooming services: prices and service costs will vary considerably from one country to another and could be sourced from local companies offering this type of services. Prices should consider both diver-based and ROV-based services • Marina fees. Prices and service costs will vary considerably from one country to another and should be sourced at least from within the region.	• Recreational service suppliers, marinas

Table 19: Data requirements and sources of information for the recreational boating sector - continued

Type of information	Specifications	Sources of information
Cleaning materials	Prevailing prices for antifouling coatings: prices and service costs should be sourced from local dealers and dry-docks or using national websites of main manufacturers or distributors of antifouling coatings.	Local suppliers
Loss of charter earnings	Average charter rates per day for general recreational fishing charter businesses. Revenue per day/ trip for most recreational charter vessels	Local service suppliers (often online)

Impact on Infrastructure

Calculating the economic impact of biofouling and IAS on infrastructure related to the recreational boating sector should focus on two key aspects:

- Increased hull roughness due to biofouling. Estimation of economic costs should follow the same method as presented in section 3.1 to calculate the cost of increased fuel consumption and additional GHG emissions.
- Other economic costs. This category would include additional cleaning or replacement costs due to IAS on tools used in the fishing industry, such as nets, cages and ropes.

The existence of a shipping industry in the country will mean that all services and tools should be locally available. Therefore, calculations should be based on local prices sourced from local service providers and/or chandlers.

3.8 Appraising the Tourism Sector

Tourism and recreation describe the service of providing a place to visit, both for national as well as foreign visitors. This service applies to both marine and freshwater ecosystems.

Because of the potential impact of IAS on environmental systems, biofouling and associated IAS can damage tourism by harming sites of commercial tourism importance. Example of harm to the tourism sector from invasive species include reduced opportunities for recreation, fishing and boating and other tourism-related businesses (Invasive Species Council of BC (Undated), Witt (2016), Invasive Specie Centre (2022), Pathak et al.. (2021). The effect of biofouling and associated IAS on the tourist sector may be thus by to reduce earnings as visitor numbers to sites and services fall.

With and Without Scenarios

Information on tourism and recreation is generally available either as absolute value in monetary terms, e.g. as total revenue per year from tourism and/or recreation (it is rarely distinguished between the two), or as relative value, e.g. data on the revenues "per visitor" or "per visit". In the second case, the value needs to be completed with information on the total number of visits or visitors to the region.

Information on tourism and recreation should be available from national tourism ministries/agencies. In case there is no information at all to be found for a specific region or smaller area, the numbers for the national level can also be used, which should be available in some form. These then need to be "broken down" to the level of the region/area. This could happen either by consulting experts, or by finding information on the share of e.g. coastal tourism in the total national tourism revenue (in the case of marine ecosystems being evaluated).

Alternatively, information on the national level can also be found at the UN World Tourism Organization (UNWTO): https://www.e-unwto.org/toc/unwtotfb/current It is unlikely that international sources will have information on the tourism and recreation in a narrow region.

In case there is no direct information available on the value of tourism even on the national level, the share of tourism in the national GDP can serve as the basis for calculating it (e.g. “X % of national GDP originate from tourism”).

Total national values, however, need to be related to the ecosystems evaluated, which can be challenging. For example, how many tourists come because of the coral reefs to a specific region, and how many because of other (natural or not) attractions. In general, the calculation of economic loss will follow along the lines of the following formulas:

Loss of gross profit = Loss of revenue - Reduced variable costs - Reduced fixed costs

Economic loss = Loss of gross profit + Additional costs incurred - Additional income from new operations.

Lost profit normally arises when revenues are reduced and the level of gross profit (revenue less costs such as wages) is less than it would normally be expected to be. The calculation can be based on the expected impact of reduced number of visitors or operational days on a certain service directly related to tourism.

It is normal for tourism and leisure visitor businesses to have high variable costs. These may differ depending on the type of business. For instance, to let a room will result in cleaning and laundry costs, a restaurant meal will include direct food and service costs. Any loss of revenue will therefore lead to a reduction in variable costs and this saving needs to be taken into account.

In relation to tourism, there can also be additional costs and income in relation to IAS. For example, management and cleaning of an invasive algae in a beach would be considered as an additional cost. On the other hand, the sale of an invasive mollusc or fish may also be the source of additional income for a restaurant, either due to reduced cost (purchasing the raw material) or a higher influx of clients.

Data requirements and possible sources of information for the tourism industry are summarised in **Table 20**.

Table 20: Data requirements and sources of information for the tourism industry

Type of information	Specifications	Sources of information
Characteristics of the sector	Collect information on visit numbers per year GDP per year	• National Status Assessment report (if available). • Relevant national ministries (tourism, Statistics, Economic Development etc.) • Chamber of commerce • UN World Tourism Organization (UNWTO)

Example. How to estimate economic loss for the Tourism industry

Rugulopteryx okamurae is an invasive algae that has recently appeared of both sides of the Strait of Gibraltar (Atlantic and Mediterranean coasts). Initial introduction is not certain, but both ballast water and hull fouling are suspect. R.okamurae is a heavy fouler along the coast. Presence on a long part of coastline on both sides of the Straight (detected beyond Marbella on the Med and after Cadiz in the Atlantic; also in Ceuta) may suggest that growth is not fuelled by land-based run offs. Beaches have been heavily fouled, forcing clean ups almost every week. An analysis of economic activities related to tourism and entertainment that could be affected include:

- Beach clean-up costs (or increased council expenditure)
- Reduced tourism revenues from international/external tourists
- Limited enjoyment of beaches by locals

The first two aspects can be determined using market pricing based on data secured in the area. The third aspect does not necessarily entail an economic activity (unless locals are paying an access fee), but it does include an existence value that requires contingent valuation methods such as willingness to pay (refer to Chapter 2 for an explanation of this aspect).

Calculation

This example will calculate the potential cost per year in relation to beach clean-up incurred by local councils.

Step 1: Determine coastline potentially at risk. While the invasion is currently affecting 3 beaches, local authorities report that a total of 12 beaches in the region could be impacted by the same IAS.

Step 2: Determine baseline costs. Council X has reported monthly cleaning costs of EUR 3,478. This includes personnel, the use of machinery and recycling algae at a local facility.

Step 3: Determine other parameters that should be included. In this case, it will be important to know how long the council will need to conduct beach clean-ups. In the example, authorities have explained that at least during 4 months of the tourist season, clean-ups will be necessary to avoid further impact on local livelihoods, highly dependent on tourism.

Economic impact: 12 beaches x 4 months x EUR 3,478 = EUR 166,944

Before entering this result in the Calculation tool, other aspects will need to be considered, such as:

- What is the expected timeframe for this impact? Will the situation be repeated in following years? In the event of an affirmative answer, the calculation should include the present value of the impact in future years (refer to Chapter 2 for further explanation on how to do this).
- Will it impact tourist revenues? Reporting the situation in the beaches, even after clean-up may make them less attractive to foreign visitors, which may result in a direct impact on local livelihoods dependent on tourists such as hotels and restaurants.

Expanding this example, this could also be applied as a case transfer in another country. Normally, if no similar risk has been detected in the second country or within its vicinity, the Incursion ration should be applied to avoid an undue weight to estimations made under a high level of assumptions. The calculation would thus be:

Number of beaches potentially at risk in Country B: 10 beaches

Tourist season in Country B: 3 months

Potential impact in Country B based on incursion rate: 10 x 3 x EUR 3,478 x 0.25 = EUR 26,085 per year

This value would still need to be adjusted to present value, US dollar and to price levels of Country B (refer to Chapter 2).

3.9 Appraising Coastal Infrastructure

The utility sector is critical to the way people live in the world today. The supply of electricity, gas, clean water, and the provision of telecommunications, both phone and internet, are all considered to be essential. Compared to total output value, biofouling and IAS have a limited effect on this sector, but they still do cause additional costs to the industry in terms of damage to infrastructure and additional control and clearance costs. Additionally, the potential existence of negative externalities on neighbouring industries derived from the use of some antifouling methods (such as Sodium hypochlorite) should be taken into account. Some examples for the water and electricity generation industries are discussed below.

Without Scenario

Impact On The Water Industry

One of the main IAS affecting this industry is the zebra mussel *Dreissena polymorpha,* one of the most invasive freshwater pests in the world. The annual cost of zebra mussels to industry in North America is estimated to be circa $5 billion (Aldridge et al. 2004). Although the creatures are smaller than 2 cm, they cling together to form large populations, which can block water pipes and outlet pipes from power stations. Estimation of the economic impact would be based on the cost of cleaning clogged pipes and any treatment applied to prevent further blockage.

Example. How to estimate the economic loss for the water industry

In this example we will use the value transfer method to estimate the impact of IAS on the water industry in Angola (under the assumption that no example is available at the national level). Using the list of EV studies we identify a case in the UK, where it was estimated that water companies have spent GBP 2.61 per kilometer of piping related to IAS in 2010.

Government reports estimate that the water network in Angola is 1,675 km in length. Based on this, the calculation for Angola would be:

Impact of biofouling and IAS on water industry: 1,675 km piping x GPB 2.61 per km = GBP 4,371 per year (2010)

The value would still need to be adjusted to present value, US dollar and to price levels of Angola. This is fully explained with examples in Chapter 4 (see page 94).

Impact on Power Generation

One of the main IAS affecting this industry is the zebra mussel or the Australian tubeworm, two well-known invasive species that block water intakes and riparian plants. Many coastal powers stations control fouling by chlorination, whilst in freshwater, where one of the most damaging fouling organisms is the zebra mussel, a variety of approaches are used including heat treatment and the use of intake screens. It has been shown that the single largest return on investment for power plants maintenance expenditure is in condenser cleaning (Conco Systems newsletter, 2008). Because nuclear power plants use large quantities of water they tend to have the highest associated costs per plant, followed by industrial plants, fossil fuel power plants, and drinking water facilities.

Estimation of the economic impact is difficult due to the different sizes and types of power stations. In this case, the suggested method would be to determine at the national level the spending related to biofouling and multiply it by the number of stations in the country.

Example. How to estimate the economic loss for the energy industry using the value transfer method

In this example we will use the value transfer method to estimate the impact of IAS on the power industry in Angola (under the assumption that no example is available at the national level). Using the list of EV studies we identify a case in the UK, where it was estimated that each station incurred an average GBP 0.00523 per Watt year.

Government reports estimate approximately 16 GW produced in Angola. Based on this, the calculation for Angola would be:

Impact of biofouling and IAS on power industry: 16 x 0.00523 per watt = GBP 8.3 million per year (2010)

The value would still need to be adjusted to present value, US dollar and to price levels of Angola.

Example. Potential savings from improved biofouling management in LNG trains

An LNG train is a liquefied natural gas plant's liquefaction and purification facility. For practical and commercially viable transport of natural gas from one country to another, its volume must be greatly reduced. To do this, the gas must be liquefied by refrigeration. Biofouling has a significant effect on the operational capacity of a pumping station. The head losses increase significantly, resulting in high additional operation costs. Even more important, due to this increased head loss the design capacity of a pumping station cannot be reached anymore.

The use of novel methods in a QatarGas LNG plant created savings of over USD 360,000 per year.

With Policy Scenario

The same calculations conducted for the 'with' scenario may now be repeated assuming that the impact of biofouling and IAS will be lower with a biofouling policy, or by applying an assumed overall reduction in costs. Where the introduction of a biofouling policy is expected to eliminate biofouling and IAS, the costs with policy will be nil. In other cases, a policy may only lessen costs. The change in biofouling levels – and associated costs – arising from a policy may be estimated based on:

- National or international documents/ research,
- Case studies from elsewhere
- Expert opinion.

3.10 Recreational Uses

Beyond revenues generated by the tourism industry there are other non-market values associated with recreational uses of the sea and seashore. These values cannot be observed directly, but are equally important in relation to its use by others (bequest value) and the value placed on the continued existence of a resource, independent of its present or anticipated use (existence value). This category may be particularly important for environmental, social and cultural resources but normally requires non-market methods such as willingness to pay and stated preference methods (refer to Annex B for further explanations on these valuation methods). Recreational values associated with the environmental that may be affected by biofouling includes non-commercial recreation. Examples of data sources to assess this section are provided in **Table 21**.

Table 21: Data requirements and sources of information for recreational uses of the environment

Type of information	Specifications	Sources of information
Recreational sector characteristics	Number of visitors/ person visits per year Any access charges (e.g., beach dues, license fees)	National or local government records Case studies from elsewhere

Example. Estimating the impact of IAS on non-use recreational values

1. Recreation: enjoyment of beaches

An invasive algae has heavily fouled 3 beaches in Country X making them less attractive to local inhabitants, who are no longer able to enjoy the beach for 7 days until the local council has cleaned the algae.

Method: Value transfer to estimate willingness to pay of nationals to enjoy beaches

Selected study: New Zealand using contingent valuation reflects a willingness to pay of USD 5 per day

Calculation:

Number of beaches at risk: 3

Average number of national tourists using each beach in a day: 500

Impact of IAS: 500 x 3 x 7 days x USD 5 = USD 52,500 (this will need to be adjusted to PPP – purchasing power parity)

2. Recreation: Existence value for dive quality

This example demonstrates how to calculate the potential impact of invasive species in dive quality along the coastline of Country X.

Calculation:

Number of coastal tourism (divers) per year: 72,000 (data secured through the Ministry of Tourism)

Method: Value transfer to estimate willingness to pay by divers for marine conservation

Selected study: Thailand using contingent valuation reflects a willingness to pay of USD 17.40 per day

WTP for dive quality: 72,000 x USD 17.40 = USD 1,252,800 per year

3. Recreation: enjoyment and existence values for angling

This example aims at calculating the impact of IAS on the quality of resources for angling opportunities in Country X.

Calculation:

It has been determined that Country X has 235 people registered for recreational fishing/angling.

Impact of potential invasion:

Enjoyment: 235 x EUR 162 = EUR 38,070 per year

Existence: 235 x EUR 76.68 = EUR 18,019 per year

(value transfer method from European Anglers Alliance)

3.11 Appraising Environmental Impacts and Non-Uses

IAS can interfere with economic activities and impact on human wellbeing particularly when they take over habitats usually occupied by other species. In economic terms, a primary concern is assessing the incremental changes that occur when IAS interfere with the functioning of an ecosystem which yields a flow of economically valuable goods and services, and (at least partially) displaces native species that are economically valuable (Emerton et al, 2008).

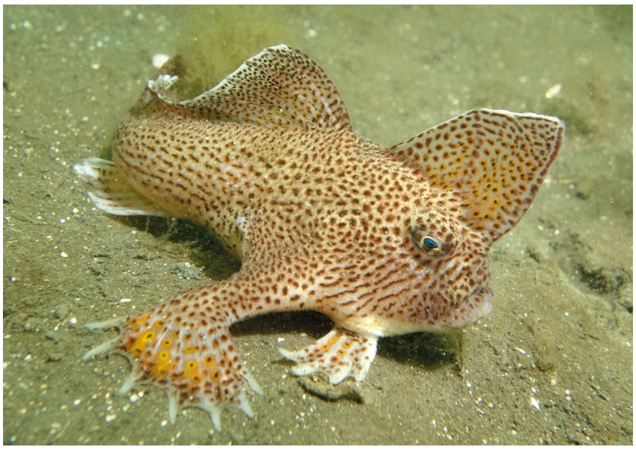
Ecological values

In addition to the potential loss of revenue through direct impacts of biofouling or IAS on maritime industries, there are some instances where IAS introduction will incur significant costs on ecosystem services, regularly and/or over long periods of time. There are possible public health impacts of bio-invasions and significant costs may be incurred both to state and private health insurers (see for example Ruiz et al., 2000, which discusses the global spread of microorganisms by ships). An interesting example can also be found in studies that indicate biofouling as a possible introduction of pathogens to shellfish aquaculture.

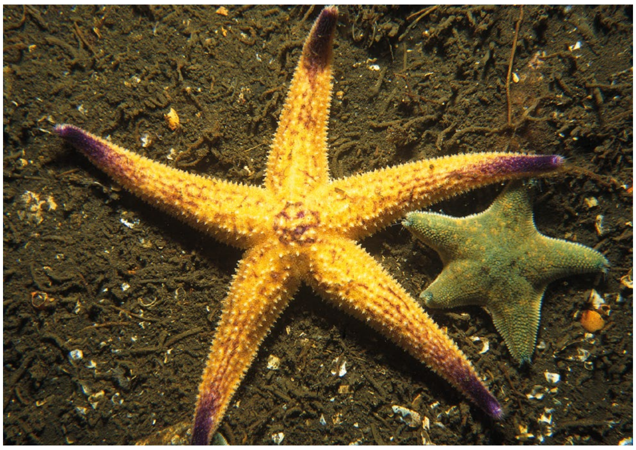
Climate change has introduced an additional challenge for management because species' ranges are shifting in response to warming temperatures (Walther et al, 2009). Climate change is expected to alter the vectors and pathways of invasion,

Box 20: Spotted Handfish

The Spotted Handfish *(Brachionichthys hirsutus)* is a small fish that lives in Tasmanian waters and is the first marine fish of modern times has been declared extinct on the IUCN RedList. It's main characteristic is that it usually uses the its fins as hands to walk across the seabed. Among other reasons, IAS have contributed to its extinction. The Northern Pacific Seastar (Asterias amurensis), a particularly large and voracious predator that is now abundant in the estuary was introduced through shipping. Studies by CSIRO demonstrated that the seastars eat the stalked ascidians that the handfish use to attach their eggs.



Spotted handfish Brachionichthys hirsutus



Asterias amurensis

enabling some species to expand into regions where they previously could not survive and reproduce (Dukes and Mooney, 1999). Unprecedented arrivals of new colonisers, as well as range expansions of established invaders, are thus expected. Yet, which species, regions and ecosystem services will be most affected by climate change remains unknown (Gallardo et al, 2019).

It must be noted that many activities cause damage to the environment which is irreversible. Should a species become extinct, it cannot be brought back. If an ecosystem is destroyed it is very difficult to restore it and so compensatory initiatives will not be able to reverse the effects of environmentally degrading ones. A cost–benefit analysis thus needs to pay more attention to questions of risk, uncertainty, sustainability and distribution, if the economic appraisal is to be reliable.

There is still much to learn about our marine biodiversity and its ecosystems. More than 4,000 currently known species have not yet been studied in detail and new species are discovered regularly. The number of known fish species increases by about 20 species per year and about half of these are new to science (Gordon et al, 2010).

Future uses of biodiversity also present difficulties to estimate in monetary terms, particularly when there are intangible and require special valuation efforts. In some instances, it may also be controversial, as it may indicate putting a price to nature.

For those cost and benefits which are difficult to measure as we may not have a market, or any measure of financial cost, we need to apply valuation techniques that entail time and resources that are not always available for preparing a rapid assessment as proposed in this Guide, and therefore, this section will rely on the existence of studies already available in a country.

For countries where no studies are available, the use of case and value transfers will be the most probable method. Further to the explanations provided in section 1.4, step-by-step illustrative examples follow here to enable users to independently conduct an economic valuation of ecosystem services using a customised value transfer approach and market prices evaluation.

	Priority to attempt valuation (highest, lowest)	Likely value (h, m, l)
Environmental value 1		
Environmental value 2		
Environmental value ...		

Table 22: Qualitative assessments of values

Further to the value transfer method, there are some industries where option values that can be linked applications of species into future potential income. This is specially the case for the pharmaceutical and cosmetic industries, where research is increasingly dependent on biological compounds.

When suitable case studies cannot be identified for value transfer, analysts are advised to consider a break-even analysis for policy, based upon consultation with environmental experts, or – at the very least – to itemiser, describe and rate the values under threat. In this case, analysts should complete **Table 22** above.

Box 21: Impact of Carijoa riisei on Hawaii's biodiversity

The Snowflake coral Carijoa riisei, threatens Hawaii's biodiversity by monopolizing food and space resources and by displacing native species. First discovered in Pearl Harbour in the 70s transported as hull biofouling and/or ballast water. In 2001, survey of the Black Coral bed in Maui discovered C. riisei overgrowing and killing over 60% of the black coral trees between 80 and 105 metres depth. It now threatens Hawaii's USD 30 million precious coral industry. Planktonic larval stage that facilitates natural dispersal via currents. The unknown long term ecological impact of C.riisei may condition the sustainable harvesting of black coral in the region.

Option Values

With 79% of the earth's surface covered by water, research into the chemistry of marine organisms is relatively unexplored and represents a vast resource for new medicines to combat major diseases such as cancer, AIDS or malaria. Research typically focuses on sessile organisms or slow-moving animals because of their inherent need for chemical defences. Standard research involves an extraction of the organism in a suitable solvent followed by either an assay of this crude extract for a particular disease target or a rationally guided isolation of new chemical compounds using standard chromatography techniques.

The bioprospecting value refers to the revenues pharmaceutical companies may be able to retrieve from the diverse genetic pool contained within a specific habitat or region.

Drug discovery from marine natural products has enjoyed a renaissance in the past few years. Ziconotide, a peptide originally discovered in a tropical cone snail, was the first marine-derived compound to be approved in the United States in December 2004 for the treatment of pain. Then, in October 2007, Trabectedin became the first marine anticancer drug to be approved in the European Union. Bioactive compounds from marine origin appear to possess stronger biological activities than their land-based counterparts (Losso, 2007).

About 30,000 compounds of marine origin are known and, since 2008, more than 1,000 compounds are newly discovered each year (Lindequist, 2016). A total of 55 to 214 new anti-cancer drugs were predicted to reach the market sourced primarily from animal phyla (Chordata, Mollusca, Porifera, and Byrozoa) and microbial phyla (Proteobacteria and Cyanobacteria). While no single aspect of extractive marine resource value should be relied upon to account for the opportunity

Example. Estimating a value for genetic biodiversity under risk

This example demonstrates how to assign a value for a species that could be threatened by a hypothetical introduction of an IAS that has been detected in a nearby region.

Fulvia fragilis is an IAS in the Bizerte lagoon in Tunisia that has an impact on ecosystem services where it has almost eradicated the native bivalve *A. paucicostata*, which was formerly frequent and abundant. Authorities are concerned of losing ecosystem services and genetic biodiversity that could potentially have future uses. In the absence of local studies, the method followed here would be to determine the value of ecosystem services using a value transfer from a suitable study that can be adjusted to the environmental characteristics of the Bizerte lagoon.

Calculation:

Using a value transfer from De Groof for determining the value of the ecosystem services at risk based on the surface area for Bizerte lagoon (150 km^2), the Ecosystem services at risk have been determined as: 15,000 x USD 6,490 ha/year = USD 97 million per year.

costs of conservation initiatives, the application of valuation models to ecosystem services further reveals the true, irreversible economic cost of habitat degradation and biodiversity declines (Erwin, 2010).

It is impossible to estimate the value of species with any precision. Even deriving an estimate for its maximum possible value would be a highly speculative exercise. However, some idea about the magnitudes involved may be determined using data from the pharmaceutical industry. A landmark study conducted in Simpson et al (1996), considers the value of "potential products" that might be derived from genetic resources as cures for diseases (existing or future) would not be higher than USD 10,000 per species. Of course, this low value was only based on potential use in the pharmaceutical industry but, applied to all the genetic species available in a habitat, the value would be considered significant.

Box 22: *Didemnum vexillum*

Native to the North West Pacific, this tunicate has been widely introduced in the Northeast and northwest Pacific and New Zealand. This species fouls hydrotechnical constructions, ships, aquaculture infrastructure and cultured mollusks. A common name for this tunicate is "carpet sea squirt" because it affects the biodiversity of existing communities as it outcompetes for habitat simply by growing over or smothering existing species and may also impact on fish spawning grounds. It is an aggressive invader that is able to reproduce sexually or asexually. Fragments of the species are able to disperse, reproduce, reattach and thrive. Fouling of man-made hard structures such as vessel hulls, aquaculture equipment, docks, moorings and support structures is common. This can prove costly to marine industries and users (Fofonoff et al., 2018) (McKenzie et al., 2017). In New Zealand, failed attempts to eradicate Didemnum in Shakespeare Bay cost NZ $650 thousand (Coutts and Forrest 2007; Forrest and Hopkins 2013). In the State of Maine, USA, the sea scallop, Placopecten magellanicus, is regularly overgrown by D. vexillum in Georges Bank and in Eastport (Valentine et al., 2007b).

Bequest and existence value

These values cannot be calculated directly, but remain important in relation to cultural values of others (bequest value) and the value placed on the continued existence of a resource, independently of its present or anticipated use (existence value). This category of non-market (non-use) values may be significant, especially in developing countries. Nevertheless, their quantification commonly involves the use of delicately designed expressed preference valuation methods (see Annex B) which, unless delivered well, can result in values that may veer substantially from their true economic value. (See FAO 2000 or Hausman 2012 for commentary on problems and effects.). High existence values can be a signal of ecosystem uniqueness, uncertainty, or a risk of irreversible or cascading impacts if the ecosystem degrades. Unfortunately, uniqueness and irreversibility are not easy to analyse in an economics framework. therefore, at the very least, the uniqueness of the system should be listed, described and a rated for possible importance, with a rationale given for the rating.

Box 23: The importance of marine biodiversity for cultural values

In New Zealand, the Māori culture has a strong relationship with te moana (our oceans and coasts), which is deeply embedded in their culture, identity and history. Maori regard the marine environment as a treasured possession (taonga). Māori have a role as kaitiaki of te moana and mātaitai (fish or food obtained from the sea). Kaitiaki are guardians who carry out the act of tiaki and look after, protect, and conserve the resource or taonga; kaitiaki can be a human, animal, or a spiritual being. Any detrimental effect of IAS on marine biodiversity can also impact the Māori ability to provide hospitality and generosity to others, including providing food for people and guests (Ministry for the Environment & Stats NZ, 2019).

Example. Estimating the impact of IAS on cultural values

Marine seashells and their role in ceremonial exchange

Seashells have been used in the past in several parts of the world as shell money – particularly species such as Monetaria moneta, Mercenaria mercenaria or Oliva carneola. This is the case of Tabu shell currency, still in use by the Tolai people around the Province of East New Britain, in Papua New Guinea. Tabu is a commodity money, similar to gold or silver coins, and valued as a medium of exchange for locally-produced goods and services (DeMeulenaere, 2002). Even in this case, the Tolai people also value Tabu for its ceremonial and customary uses, particularly during weddings and funerals. Shell money is mostly acting as a substitute of our current currencies for the payment of goods, so there was a clear market value of shell money.

However, and beyond the use as shell money, seashells have also been used for more cultural aspects that are not always directly linked to monetary transactions. The case of Kula rings in the Tobriand Islands, Papua New Guinea, is a good example of the role that marine species can play within a ceremonial exchange system. Kula valuables are non-use items made of large white spondylus shells and traded for establishing a kingship relationship between the two exchanging parties, for purposes of enhancing social status and prestige and even sometimes for establishing a commercial relationship between two parties in different islands. The partnership involves mutual obligations such as hospitality, protection and assistance, but the Kula never remains long in the hands of the recipient and it is past on for another partnership with a third person, in a constant circle of exchanges. Although ownership remains with the first person that exchanged the Kula ring, it is often quite difficult to determine who was the ultimate owner of a ring. Kula rings are the basis of a complex system of based on trust that uses gifts and counter gifts to establish strong social obligations (Mauss, 1970).

To date no studies have attempted to determine the value of this system. It would indeed be difficult to price it at any stage. At the time of printing this publication, a few Kula rings were sold over popular internet commercial sites at a wide range of prices (from USD 500 to USD 2,300, source: author 2020). Considering there are thousands of Kula objects in circulation, an extremely simplified conclusion would argue that the whole system could be valued at over USD 50 million. However, this does not really reflect the important symbolic role that Kula rings play in the society of the Trobriand Islands. A more comprehensive analysis could use contingent valuation methods to establish the full value that society would attribute to the Kula system, beyond the material value of the rings (but refer to the limitations of contingent valuations mentioned in Annex B).

4 Costing the Development and Implementation of Policy

The calculations explained in previous chapters are aimed at identifying the economic impact of marine biofouling and IAS on maritime industries and ecosystem services and the costs of improving biofouling management. This chapter will help readers to estimate the costs in relation to the development and implementation of the policy itself. The purpose is twofold:

- determine the **economic cost** of a national policy for the purpose of a full CBA; and
- identify the **financial needs** and develop a feasibility assessment that identifies what items will require budget allocations.

It is imperative to understand the difference between these two concepts: Economic costs include in-kind services as well as expenditure and income related to the development and implementation of the policy. Within the context of a CBA of a national policy, the true cost will be compared to alternative scenarios, i.e. in our case, the cost of not taking any action.

On the other hand, the financial needs would not include in-kind services and only consider potential expenditure and income related to a policy. Additionally, a feasibility assessment should focus on identifying capacities and needs related to the policy that would require budget allocations, while also exploring potential sources of finance. **Table 23** below describes the main components for each concept within the two broad stages related to the development and implementation of a national policy.

The main reference for the calculations explained in this chapter should be the National Biofouling Management Strategy and the associated Action Plan. These documents will give a detailed indication of the needs identified for the country and the different steps that have been determined for the development and implementation of a national policy. In the absence of an existing National strategy (or during its early stages of development), a preliminary estimation can be made using the indications provided in this chapter. Likewise, the Guide to Developing National Biofouling Strategies on Biofouling Management to Minimize the Introduction of Invasive Aquatic Species, published by the GEF-UNDP-IMO GloFouling Partnerships, can provide further guidance on the main aspects that should be considered.

For all aspects, costs should be determined using market prices, that is, identifying the fair value of the goods and services prevailing in the country at the time of the developing this Report. As illustrated in **Figure 8** (see next page), the chapter will first discuss costs related to the development of a national strategy (Strategy development phase), followed by an analysis of the main cost items related to the implementation of the strategy (Implementation phase).

Table 23: Understanding the main financial components to be considered

Item	True cost of national policy	Financial needs
Strategy development phase	Present Value (PV) of in-kind resources + PV of expenditure (e.g. material purchases and external/additional support)	PV of expenditure (e.g. material purchases and external/additional support)
Implementation phase	PV of in-kind resources + PV of expenditure (e.g. material purchases and external/additional support) - PV of income related to sanctions regime (if it exists)	PV of expenditure (e.g. material purchases and external/additional support) - PV of income related to sanctions regime (if it exists)

Figure 8 - Phases of strategy development and implementation

4.1 Strategy Development Phase

Generally, the initial step to develop a biofouling strategy is to assess institutional needs and the exposure to IAS and the different pathways and vectors related to biofouling. This preparatory work would start by identifying a team or group of people that would be commissioned to develop the strategy, normally led by a Lead Agency. In addition, overcoming inter-agency coordination challenges will require development of a national task force (inter-agency forum or communication mechanism) to coordinate consultations among, as well as between, national and regional level governance structures and other key stakeholders that may be identified to play a role in the development of a national policy.

Costs associated with this phase will largely arise from the time spent by officials and experts in coordination and carrying out the series of tasks related to the following outputs:

- National task force meetings
- Baseline assessments (country status; stakeholder analysis; economic; surveys)
- Development of national strategy
- Development of voluntary guidelines or mandatory regulations
- Stakeholder consultations

Typical items that need to be considered for the above outputs are listed in **Table 24** below, followed by some examples for the calculation.

Table 24: Key components to be considered for the Strategy development phase

Item	Main variable	Unitary cost	Other variables	Availability
Meetings and consultations				
List the types of meetings or consultation processes that will be required	Approximate number of meetings and consultations estimated at all levels (with consideration over annual spread)	Number of staff, personnel and/ or professional services and approximate unitary cost (e.g. salary per day);	Approximate number of hours or days estimated for each meeting	Existing resources (e.g. in-kind services) or external (requires monetary payment). Temporal distribution
Studies, reports or assessments to be commissioned				
List the reports that will be required (e.g. baseline assessments, surveys, strategy, etc)	Number of reports	Approximate cost of developing each type of report	If applicable, cost of procurement services (tender assessment, etc.)	Existing resources (e.g. in-kind services) or external (requires monetary payment). Temporal distribution

Table 24: Key components to be considered for the Strategy development phase - continued

Item	Main variable	Unitary cost	Other variables	Availability
Logistics				
Description of each category (e.g. travel expenses; meeting rooms, etc.)	Number for each category	Approximate unitary cost for each category	Number of days or hours in relation to each logistic	Existing resources (e.g. in-kind services) or external (requires monetary payment)
Other materials or items				
Description of each material item required	Number of items for each type	Unitary cost of each type of item (purchase or rental).	Not applicable	Existing resources (e.g. in-kind services) or external (requires monetary payment)

Box 24: How to estimate the cost of the Strategy development phase

The cost for the Strategy development phase would be obtained by the following formula:

Cost of Strategy development phase =
Total cost of NTF meetings + Total cost Baseline reports + Total cost of strategy development

Additionally, it is important to remember that costs related to the preparatory phase would possibly be incurred over several years, and not necessarily in a single/same year. It is therefore important to convert these calculations into the present value by applying a suitable discount rate (refer to Chapter 2/Step 5: Temporally distributed impacts). The total cost for the Strategy development phase would be obtained by adding the net present value of all the components that have been identified in the formula above.

Example. Estimating common costs of different phases in strategy development

National task force (NTF) meetings

A. Number of participants	Typically representing all relevant institutions and stakeholders at the national level
B. Average salary per day of participants or officials	This is an approximation, based on national salary rates and using the national currency
C. Days per meeting	NTF meetings would be expected to last one or two days
D. Number of meetings	It is assumed that NTFs would meet at least once or twice a year to review the key processes and documents related to the development of a national policy. The estimation should consider how many years would be typically necessary for developing a national policy and regulations
Total cost NTF meetings	A x B x C x D

Example. Estimating common costs of different phases in strategy development - continued

Baseline reports

A. Average salary per day national expert or official	Estimated number, based on national salary rates and using the national currency	
B. Status assessment	A x number of days	At least 20 working days should be allocated for the development of this report
C. Economic assessment	A x number of days	At least 20 working days should be allocated for the development of this report
D. Legal assessment	A x number of days	At least 20 working days should be allocated for the development of this report
Total cost Baseline reports	B + C + D	

Development of national strategy and regulations (or voluntary guidelines)

A. Average salary per day national expert or official	This is an approximation, based on national salary rates and using the national currency. It could also be commissioned to external consultants.	
B. National strategy	Number of people x number of days x A	Normally developed and reviewed by several officials or professionals
C. Drafting national voluntary guidelines or mandatory regulations	Number of people x number of days x A	Normally developed and reviewed by several officials or professionals. It could include a preliminary impact assessment with industry stakeholders.
Total cost national strategy and regulations	B + C	

4.2 Implementation Phase

The second stage of government costs would focus on the costs related to the approval of the national biofouling regime, the development and implementation communications, training of relevant administration staff and port state control officers and the monitoring requirements set by the country. Costs associated with this phase will largely depend on the requirements identified in the national strategy, and particularly if the country will opt for voluntary guidelines or a mandatory regulation. Prior to the development of the strategy (or in its early development stages), the estimation should be based on some general assumptions and costs and requirements should be discussed at length with relevant members of the NTF. **Figure 9** (see next page) illustrates some of the main considerations that could be included in a policy. **Table 25** (see page 99) discusses in more detail the implications related to each item that can facilitate an estimation of the cost, what type of funding will be required and from where it will be sourced.

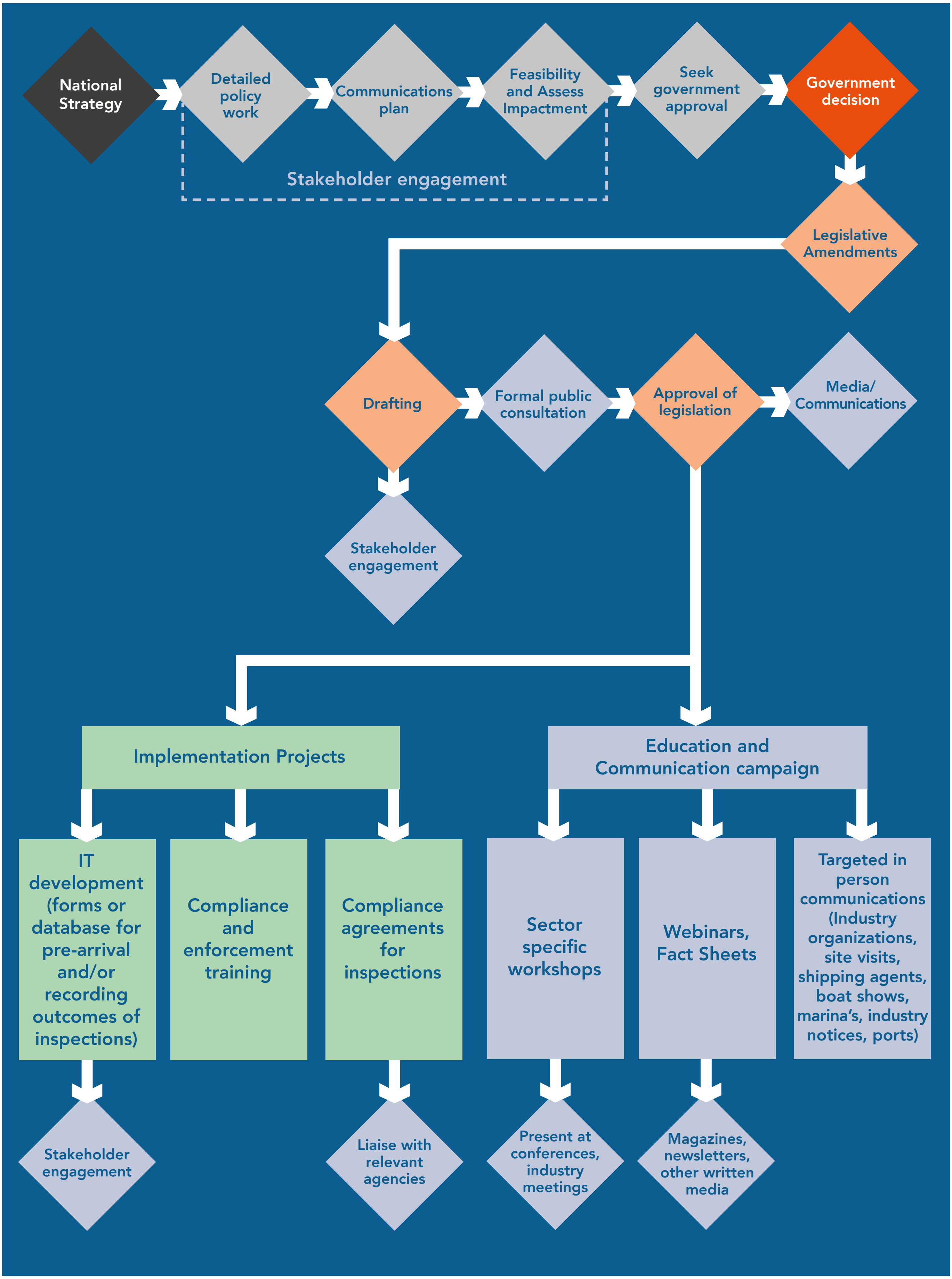


Figure 9: Processes and stakeholder interaction during the Implementation phase

Table 25: Key elements to be considered for the Implementation phase

Item	Main variable	Unitary cost	Other variables	Availability
Approval of national biofouling regime				
The approval process will be specific to each country's political framework, particularly in the case of mandatory regulations that may require, for example, parliament approval. The cost of this process will therefore be subject to very different variables from one country to another. Preliminary estimation should be conservative and perhaps aim at determining typical stages for the approval of a normative regime and allocating a proportionate number of people hours that could be directly related. Once the National strategy identifies the selected option, cost estimations should be updated. The calculation should also assess what items would be developed using existing resources (e.g. in-kind services) or external (requires monetary payment) and a timeline for implementation. Normally, no budget allocation would be required for the approval process, as it would be part of the political framework already in place in the country.				
Communication				
A communications strategy and plan would be expected to publicize the policy with different stakeholder groups. It can be developed either internally using a media department of the government or through independent communication consultants. The communications strategy will include a plan listing the different items and actions that would be required and provide some insight into what resources or professional services will be necessary. As for the previous item, the calculation should also assess what items would be developed using existing resources (e.g. in-kind services) or external (requires monetary payment) and a timeline for implementation.				
Monitoring				
The national strategy would normally define a monitoring and inspections regime based on set number of levels. This may include defining a risk assessment mechanism to prioritise and determine the best use of resources related to monitoring and inspection, and could entail, for example, the development or acquisition of a risk assessment model in the form of procedures and/or software to assist the decision-making process. Within the monitoring programme two key aspects would normally be considered: compliance by industry and biological impact. • Compliance monitoring would normally be under the purview of national officers. The national policy should include the different phases or steps related to an inspections regime. For example, inspections could primarily be based on the review of Biofouling Management Plans and record books, leaving detailed physical inspections only for extreme cases where a certain level of irregularities is detected. Detailed inspections may require either with the use of simple technologies such as poles with cameras or through the use of drones or divers for more extreme cases. These inspections could be part of the cost recovery mechanisms discussed in the next section. • The country may also decide to create a programme of regular environmental surveys to assess the effectiveness of the biofouling regulations and detect any potential invasions. The estimation should include the cost of developing initial port baseline surveys (unless already available) in key ports and the cost of a monitoring programme over several years. Where possible, it should consider the use of national resources (marine biologists, laboratory, etc.). For a preliminary calculation of the costs related to monitoring and inspection, data will be required on the annual traffic movements, the main ship types or categories and the number of inspections or enforcement practices currently undertaken by national PSC authorities.				

Table 25: Key elements to be considered for the Implementation phase - continued

Item	Main variable	Unitary cost	Other variables	Availability
Training				
Specialised trainings would be aimed at officers and other stakeholders expected to implement the biofouling management regulations, with specific content on inspection procedures and best practices for in-water cleaning, dry-dock operations and application of antifouling coatings. These can include national officers from the flag/port state control administration, or even private sector employees. Calculations should also consider the use of a national training institution that could provide training in the long term. Data will need to review current inspection and enforcement practices for other maritime requirements and identify at least the number of PSC officers that would undertake potential inspections and if, for example, support will be required from other national officers with different specializations (e.g. Biosecurity). As with previous categories, the calculation should also assess what items would be developed using existing resources (e.g. in-kind services) or external (requires monetary payment) and a timeline for implementation.				

Box 25: How to estimate the cost of the Implementation phase

The cost for the Implementation phase would be obtained by the following formula:

Cost of Implementation phase =
Total cost of approval + Total cost of Communications plan + Total cost Training regime + Total cost of Monitoring and risk assessment

Additionally, it is important to remember that costs related to the implementation phase will be incurred over several years, and not necessarily in a single/same year. It is therefore important to include these costs and to convert them into the present value by applying a suitable discount rate (refer to Chapter 2: Temporally distributed impacts). The total cost for the Strategy development phase would be obtained by adding the net present value of all the components that have been identified in the formula above.

Example. Estimating the cost of the implementation phase

Approval of national biofouling regime

A. Average salary per day national expert or official	This is an approximation, based on national salary rates and using the national currency. It could also be commissioned to external consultants.	
Review and approval process for national voluntary guidelines or mandatory regulations	Number of people x number of days x A	This calculation should assess the number of people and the time they will invest in reviewing and approving the proposed solution.

Example. Estimating the cost of the implementation phase - continued

Communication

A. Development of a communication strategy	Example: 3 media officers developing strategy over two days	The cost should be estimated based on either the time dedicated to the development of the strategy, in the first case (as in the example), or the approximate fees that could belong to the second option.
B. Development of communication materials	This part would try to determine the approximate cost of any materials that could be identified in a communications strategy. Examples could be a website for communication, leaflets, posters and banners. The estimation should consider the cost of design and printing.	
C. Communication and awareness raising campaign	The cost of any actions to implement the communications strategy. For example, the cost of maintaining a website, distributing leaflets, and holding meetings and events with industry associations, port and dry docks and the recreational sailing community.	
Total cost Communication	B + C + D	

Training

A. Basic general training of national officials	While training packages could be potentially sourced from IMO, GloFouling Partnerships, industry associations or national training institutions, this section should consider at least the cost of trainers and the time of participants attending the training courses. This can be done by determining the average salary of participants and the number of days of training.
B. Specialised training	While training packages could be potentially sourced from IMO, GloFouling Partnerships, industry associations or national training institutions, this section should consider at least the cost of trainers and the time of participants attending the training courses. This can be done by determining the average salary of participants and the number of days of training.
Total cost Training	A + B

Monitoring and risk assessment

A. Risk assessment	Consideration should be given to the development or acquisition of a risk assessment model in the form of procedures and/or software to assist the decision-making process.
B. Inspection	Very much related to an estimation of the number of inspections that would be required based on the It is expected that a document-based analysis would not require more than 30 minutes and already be part of other obligations undertaken by flag state and port state control officers. Cost of detailed inspections should be based on the cost of inspecting materials or the use of divers and an estimation of the number of days that would be required.
C. Biological monitoring	Costs related to annual monitoring surveys of key areas or ports. Should include an estimation of the cost of sampling materials, specialised personnel, divers (if required) and laboratory/analysis fees.
Total cost Monitoring	A + B + C

4.3 Sources of Income

It is reasonable to assume that most of the burden related to preventing bio-invasions through biofouling will be borne by maritime industries, particularly because there could be incentives in the form of benefits or reduced operating costs derived from managing biofouling. Additionally, there are cost implications associated with the provision of port services, risk assessment, monitoring and inspection that could be recovered or distributed in order not to incur excessive costs to the Administration.

Funding mechanisms, particularly for the preparatory phase, include private sector investors, commercial bank loans; government (through additional allocations in national budget and/or subsidies), and multilateral donors (such as IMO's Technical Cooperation Fund, international financial institutions and the GEF-UNDP-IMO GloFouling Partnerships).

For the implementation phase, consideration should be given to potential cost recovery mechanisms or sources of income that can result from fees received from licensing services to private sector companies for providing services such as in-water cleaning, management of biofouling sediments, etc.

Non-compliance with biofouling regulations can constitute a significant, albeit irregular, source of revenue from fines imposed on companies or individuals not complying with regulations that have been set in the country (if this is the case). Companies could also be charged for costs related to detailed inspections (such as using divers) after a certain threshold of biofouling has been detected. In any case, where fines for non-compliance are imposed, the polluter pay principle and/or the shared cost principle should be applied.

In summary, the funding for activities in the preparatory phase and for measures introduced by the flag/port/coastal state could be a mix of funding and cost-recovery mechanisms, as necessitated by each country choosing to use a variety of funding mechanisms. **Table 26** summarizes the strengths and weaknesses of various mechanisms, their potential revenue streams and reliability (adapted from GloBallast, 2010).

Table 26: Consideration of potential revenue streams

Financing mechanism for BWM related costs	Potential size of funds that can be mobilized	Sustainability of funds over time	Ease of collection and administration	In line with polluter pays principle	Political feasibility
Fines and penalties	M	L-M	M	H	H
Cost recovery of inspections	M	M	M	H	H
Fees for services	H	H	M	H	H
Government funds	M	L-M	H	L	L-M
Partnerships with private sector, NGOS	L	L	M-H	H	M

Income estimations should be based on realistic figures as much as possible. For Shipping, they could be based on the number of international arrivals per year, determining an average growth (or decrease) rate, and setting a suitable percentage for each potential event, as per the example below.

Example. Estimating potential income or cost recovery for the shipping industry

Fines or penalties

A. Number of arrivals	Number of ship arrivals per year (average or annual projection of international ships to national ports)
B. Fines or penalties	Fees related to fines or penalties set out in the national regulation – It is important to understand that there could be different categories in relation to the graveness of non-compliance or if there is any recurrence. The Lead Agency should be consulted for more details on the types of fines and penalties applied in similar legislation.
C. % ships	For each category, estimated % of non-compliant ships. It is recommended that this should be a conservative figure and based on the assumption that, after an initial adaptation phase, most ships would be compliant (typical examples would be applying 1% for the most severe fines, and 5% for the less severe).
Total income from penalties	For each category of non-compliance, A x B x C

Cost recovery of inspections

A. Number of arrivals	Number of ship arrivals per year (average or annual projection of international ships to national ports)
B. % inspections	Estimated % of non-compliant ships – the same percentages used above (Fines and penalties – item C) should be applied.
C. Cost of inspections	Fees applicable to each category of inspections (e.g. ROV inspection hull survey, diver-based inspection, dock fees). These services could be using State-owned resources or offered through a third party (commercial services). Regardless of the modality, prices should be established on cost recovery basis (i.e. additional income would be sourced from fines or penalties).
Total cost Baseline reports	For each category of inspections: A x B x C

Fees for services

There are a number of emerging port-based technologies and services for hull and infrastructure maintenance that could warrant income for the port authority or a local entity. Additionally, managing the disposal and (possible) recycling of biofouling waste would also provide a source of income to a port authority or local governance entity. This income would normally be source from operating license fees to commercial entities. Regardless of the above, care should be taken for not duplicating potential income based on these services, as they have already been considered as part of the potential benefits for ports (Chapter 3, Section 3.2). The guiding principle would be based

In any case, estimations should be based on the number of ship arrivals per year and an assumption of the % of ships that would require cleaning services.

For the Aquaculture industry, a similar estimation can be made, based on the number of farms or pens existing in the country. Consideration could also be given to the existence of port-based services such as lease of cleaning areas and reception and/or recycling biofouling sediments. However, care should be taken when making these estimations, as most aquaculture companies may already develop these services in-house.

Before ending this chapter, it is important to remember that any estimation of income would also be subject to the time spread of its actual availability and should therefore be converted to the present value by applying the same discount rate selected for the report (refer to Chapter 2/Step 5: Temporally distributed impacts).

Annex A

Ship Fuel Consumption and GHG Emissions

Ship type	Ship size	Size units	Avg consumption ('000 tonnes)	Avg CO_2 emissions ('000 tonnes)	Avg CO^2 emissions per fuel tonne
Bulk carriers	0-59,999	dwt	3.26	12.97	3,979
	60,000-99,999	dwt	5.40	21.09	3,906
	100,000 +	dwt	8.97	32.68	3,643
Chemical tankers	0-9,999	dwt	1.19	7.22	6,067
	10,000 +	dwt	4.17	17.48	4,192
Liquified gas tanker	0-49,999	cbm	2.40	12.21	5,088
	50,000-199,999	cbm	17.90	65.95	3,684
	200,000 +	cbm	35.50	125.72	3,541
Oil tankers	0-19,999	dwt	0.80	9.68	12,100
	20,000-199,999	dwt	5.70	28.00	4,912
	200,000 +	dwt	15.30	62.90	4,111
Container	0-2,999	TEU	5.05	23.41	4,636
	3,000-7,999	TEU	16.00	65.56	4,098
	8,000 +	TEU	24.26	92.17	3,799
General cargo	All vessel sizes	dwt	1.28	7.23	5,648
Vehicle	All vessel sizes	Vehicle	7.79	31.57	4,053
Ro-Ro	0-4,999	dwt	1.10	31.09	28,264
	5,000 +	dwt	6.80	33.95	4,993

Ship type	Ship size	Size units	Avg consumption ('000 tonnes)	Avg CO_2 emissions ('000 tonnes)	Avg CO^2 emissions per fuel tonne
Ferry (ro-pax)	0-1,999	gt	0.60	5.89	9,817
	2,000 +	gt	6.00	25.58	4,263
Ferry (pax only)	0-1,999	gt	0.80	9.58	11,975
	2,000 +	gt	3.90	20.65	5,295
Cruise ships	0-9,999	gt	0.71	13.16	18,535
	10,000 +	gt	24.62	136.27	5,535
Yachts	All vessel sizes	gt	0.40	3.14	7,850
Fishing	All vessel sizes	gt	0.40	11.30	28,250
Service tugs	All vessel sizes	gt	0.40	4.22	10,550
Offshore	All vessel sizes	gt	0.70	5.39	7,700
Service vessels	All vessel sizes	gt	0.70	4.26	6,086

Source: Adapted from bottom-up calculations (IMO, 2020).

Annex B

Valuation Methods

Following is a list of valuation methods, grouped by general type (revealed or expressed preference type). It should be noted that the different methods may measure different components of economic value, so the values generated may not be directly comparable. 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 valuation methods – links to more information on this subject are available in Annex E.

Revealed preference methods

Valuation Method	Approach	Application to Ecosystem Services	Example Ecosystem Service	Limitations
Damage cost avoided	Estimate damage avoided due to ecosystem service	Ecosystems that provide storm, flood or landslide protection to houses or other assets	Coastal protection by dunes; river flow control by wetlands; landslide protection by forests	Difficult to quantify changes in risk of damage to changes in ecosystem quality
Defensive expenditure	Expenditure on protection of ES	ES for which there is public or private expenditure for its protection	Recreation and aesthetic values from 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
Hedonic pricing	Estimate influence of environmental characteristics on price of marketed goods	Environmental characteristics that vary across goods (usually houses)	Urban green open space; air quality moderated by ecosystems	Technically difficult. High data requirements. Limited to ES that are spatially related to property locations
Market price method	Prices for ES that are directly observed in markets	ES that are traded directly in markets	Timber and fuel wood from forests; clean water from wetlands	Market prices can be distorted e.g. by subsidies. Most ES are not traded in markets
Production method	Statistical estimation of production function for a marketed good including an ES input	Ecosystems that provide an input in the production of a marketed good	Soil quality or water quality as an input to agricultural production	Technically difficult. High data requirements
Public pricing	Public expenditure or monetary incentives (taxes/ subsidies) for ES as an indicator of value	ES for which there are public expenditures	Watershed protection to provide drinking water; Purchase of land for protected area	No direct link to preferences of beneficiaries

Valuation Method	Approach	Application to Ecosystem Services	Example Ecosystem Service	Limitations
Replacement cost	Estimate the cost of replacing an ES with a man-made service	ES that have man-made equivalents	Coastal protection by dunes (replaced my seawalls); water storage and filtration by wetlands (replaced by reservation and filtration plant)	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 the benefits of the original ecosystem
Restoration cost	Estimate cost of restoring degraded ecosystems to ensure provision of ES	Any ES that can be provided by restored ecosystems	Coastal protection by dunes; water storage and filtration by wetlands	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 the benefits of the original ecosystem.
Travel cost	Estimate demand for ecosystem recreation sites using data on travel costs and visit rates	Recreational use of ecosystems	Recreational use of national parks	Technically difficult. High data requirements. Limited to valuation of recreation. Complicated for trips with multiple purposes or to multiple sites

Expressed preference methods

Valuation Method	Approach	Application to Ecosystem Services	Example Ecosystem Service	Limitations
Choice modelling (choice experiment)	Ask people to make trade-offs between ES characteristics and monetary costs or benefits	Suitable for evaluating bundles of ES when there is interest in the marginal value of each	Biodiversity; recreation; landscape aesthetics; flood risk attenuation	Technically difficult to implement. Highly context-dependent with risk of biases in design and analysis. People need to understand what is being valued.

Valuation Method	Approach	Application to Ecosystem Services	Example Ecosystem Service	Limitations
Contingent valuation	Ask people to state their willingness to pay for an ES.	Suitable for ES that may be considered an indivisible whole	Biodiversity; recreation; landscape aesthetics; flood risk attenuation	Highly context-dependent. Risk of biases in design and analysis. People need to understand what is being valued.
Group / participatory valuation	Ask groups of stakeholders to state their willingness to pay for an ES through group discussion	All ecosystem services	Biodiversity; recreation; landscape aesthetics; flood risk attenuation	As above, but also risk of biases due to group dynamics

Other methods

Valuation Method	Approach	Application to Ecosystem Services	Example Ecosystem Service	Limitations
Benefit transfer (or Value transfer)	Transfer economic values for ecosystem services from studies already completed to another site (sometimes with some calibration)	All ecosystem services	Any	Relies on finding studies in sites of similar conditions (e.g., population, resource use, environmental change) Case studies must themselves have been delivered using robust methods

Annex C

Classification of Marine Ecosystem Services

Ecosystem service	Description
Provisioning services	
Food provision	Provision of biomass from the marine environment for human consumption. This includes all industrial, artisanal and recreational fishing activities and aquaculture.
Water storage and provision	Provision of water for human consumption and other uses. In the marine environment, these uses are mainly associated with coastal lakes, deltaic aquifers, desalination plants, industrial cooling processes, and coastal aquaculture in ponds and raceways.
Biotic materials and biofuels	Provision of biomass or biotic elements for non-food purposes, including medicinal (e.g. drugs, cosmetics), ornamental (e.g. corals, shells) and other commercial or industrial purposes, such as fishmeal, algal or plant fertilisers, and biomass to produce energy or biogas from decomposing material.
Regulating and maintenance or supporting services	
Water purification	Biochemical and physicochemical processes involved in the removal of wastes and pollutants from the aquatic environment, including treatment of human waste, dilution, sedimentation, trapping or sequestration (e.g. of pesticide residues or industrial pollution); bioremediation; oxygenation of "dead zones", filtration and absorption; remineralisation; and decomposition.
Air quality regulation	Regulation of air pollutant concentrations in the lower atmosphere.
Coastal protection	Natural protection of the coastal zone against inundation and erosion from waves, storms or sea level rise by biogenic and geologic structures that disrupt water movement and thus stabilise sediments or create protective buffer zones.
Climate regulation	The ocean acts as a sink for greenhouse and climate active gasses, as inorganic carbon is dissolved into the seawater and used by marine organisms, a percentage of which is sequestered; perennial large algae and higher plants can store carbon for longer periods.

Ecosystem service	Description
Regulating and maintenance or supporting services	
Weather regulation	Influence on the local weather conditions, e.g. the influence of coastal vegetation and wetlands on air moisture and, eventually, on the saturation point and cloud formation.
Ocean nourishment	Natural cycling processes leading to the availability of nutrients in seawater to produce organic matter.
Lifecycle maintenance	The biological and physical support to facilitate the healthy and diverse reproduction of species; this mainly refers to the maintenance of key habitats that act as nurseries, spawning areas or migratory routes.
Biological regulation	Biological control of pests. The control of pathogens especially in aquaculture installations, the role of cleaner fish in reefs, biological control on the spread of vector borne human diseases, and the control of invasive species.
Cultural services	
Symbolic and aesthetic values	This is about the exaltation of senses and emotions by seascapes, habitats or species, and values put on coastal natural and cultural sites, and on the existence and beauty of charismatic habitats and species such as corals or marine mammals.
Recreation and tourism	Opportunities that the marine environment provides for relaxation and entertainment, including coastal activities such as bathing, sunbathing, snorkelling, SCUBA diving, and offshore activities such as sailing, recreational fishing, and whale watching.
Cognitive effects	Inspiration for arts and applications (e.g. architectural designs inspired by marine shells, medical applications replicating marine organic compounds), material for research and education (e.g. as test organisms for biological experiments), information and awareness (e.g. respect for nature through the observation of marine wildlife).

(Adapted from Liquete et al, 2013).

Annex D Glossary of Terms

Anti-fouling System	A coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms
Biofouling	The accumulation of aquatic organisms, such as microorganisms, plants and animals, on surfaces and structures immersed in, or exposed to, the aquatic environment. May include microfouling and macrofouling.
Biofouling Guidelines	*Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (resolution MEPC.207(62)), 12 November 2011.
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 bene t that consumers derive from the consumption of a good or service over and above the price they have paid for it.
Contingent valuation	Contingent valuation is a survey-based economic technique for the valuation of non-market resources, such as environmental preservation or the impact of contamination. It involves determining the value of an ecosystem service by asking what individuals would be willing to pay for its presence or maintenance.
Cost-Benefit Analysis	An evaluation method that assesses the economic efficiency of policies, projects or investments by comparing their costs and benefits in present value terms. This type of analysis may include both market and non- market values and accounts for opportunity costs.
Demand	The amount of a good or service consumed or used at a given price; consumers will demand a good or service if the bene t 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: $\sum_{t=0}^{T} X/(1+r)^t$
Economic activity	The production and consumption of goods and services. Economic activity is conventionally measured in monetary terms as the amount of money spent or earned and may include 'multiplier effects' of input costs and wages

Economic benefit	The net increase in social welfare. Economic benefits include both market and non-market values, producer and consumer benefits. Economic benefit refers to a positive change in human wellbeing.
Economic contribution	The gross change in economic activity associated with an industry, event, or policy in an existing regional economy.
Economic cost	A negative change in human wellbeing.
Economic impact	The net changes in new economic activity associated with an industry, event, or policy in an existing regional economy. It may be positive or negative.
Economic value	i) The monetary measure of the wellbeing associated with the production and consumption of goods and services, including ecosystem services. Economic value is comprised of producer and consumer surplus and is usually described in monetary terms. Or ii) The contribution of an action or object to human wellbeing (social welfare).
Ecosystem functions	The biological, geochemical and physical processes and components that take place or occur within an ecosystem.
Ecosystem service approach	A framework for analysing how human welfare is affected by the condition of the natural environment.
Ecosystem service valuation	Calculation, scientific and mathematic, of the net human benefits of an ecosystem service, usually in monetary units.
Ecosystem services	The benefits that ecosystems provide to people. This includes services (e.g. coastal protection) and goods (e.g. fish).
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
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.
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.
Gross revenue	Money income that a firm receives from the sale of goods or services without deduction of the costs of producing those goods or services. Gross revenue from the sale of a good or service is computed as the price of the good (or service) multiplied by the quantity sold.
Gross value	The total amount made as a result of an activity.
Guidance for Recreational Craft	*Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull Fouling) for Recreational Craft* (MEPC.1/Circ.792), 2012.

Hedonic pricing method	A method for pricing ecosystem services. Hedonic price models assume that the price of a product reflects embodied characteristics valued by some implicit or shadow price.
Indirect use value	The value of ecosystems services that contribute to human welfare without direct contact with the elements of the ecosystem, for example regulating services such as plants producing oxygen or coral reefs providing coastal protection.
In-kind contributions	Donations of goods or professional services donated by groups such as organizations, corporations, small businesses, vendors, colleges, individual professionals or tradespeople. — instead of cash.
Intermediate costs	The costs of inputs or intermediate goods that are used in the production of final consumption goods. For example, the cost of fishing gear used to catch fish is an intermediate cost to the harvest and sale of fish.
Intrinsic value	The value of something in and for itself, irrespective of its utility to something or someone else. Not related to human interests and therefore cannot be measured with economic methods.
Marginal value	The incremental change in value of an ecosystem service resulting from an incremental change (one additional unit) in the quantity produced or consumed.
Market value	The amount for which a good or service can be sold in a given market.
Negative externality	Negative externalities occur when the consumption or production of a good causes a harmful effect to a third party.
Net Present Value	The difference between the present value of inflows and the present value of outflows over a period of time.
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.
Niche areas	Areas on a ship that may be more susceptible to biofouling due to different hydrodynamic forces, susceptibility to coating system wear or damage, or being inadequately, or not, painted, e.g., sea chests, bow thrusters, propellor shafts, inlet gratings, dry-dock support strips, etc.
Nominal	The term 'nominal' indicates that a reported value includes the effect of inflation. Prices, values, revenues etc. reported in 'nominal' terms cannot be compared directly across different time periods. See also real and constant prices.
Non-use value	The value that people gain from an ecosystem that is not based on the direct or indirect use of the resource. Non-use values may include existence values, bequest values and altruistic values.
Opportunity cost	The value to the economy of a good, service or resource in its next best alternative use.

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

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

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 bene t to producers. Although they differ slightly, the terms are used synonymously for this report to represent economic value.

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

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

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

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 (ecosystem services) derived from any ecosystem, 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. As opposed to value in exchange.
User cost	The cost incurred over a period of time by the owner of an asset as a consequence of using it to provide a flow of capital or consumption services. I.e. the implications of current consumption decisions on future opportunity. User cost is the depreciation on the asset resulting from its use.
Valuation	The process or practice of estimating human benefits of ecosystem services or costs of damages to ecosystem services, represented in monetary units.
Value	An expression of magnitude of preference.
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.

Annex E

Other Sources of Information

- JWRI guidance toolkit on coastal capital
- VALUES Methods for integrating ecosystem services into policy, planning, and practice
- UNEP guidance toolkit on value transfer
- Ecosystem Services Valuation Database (ESVD)
- The Economics of Ecosystems and Biodiversity (TEEB)
- Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States
- NEP Guidance toolkit for the valuation of regulating services
- Economic Valuation of Environmental and Resource Costs and Benefits in the Water Framework Directive: Technical Guidelines for Practitioners.
- Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services.
- An introductory guide to valuing ecosystem services
- The Measurement of Environmental and Resource Values.
- Handbook on Biodiversity Valuation.
- Economic Valuation with Stated Preference Techniques Summary Guide
- An instrument for assessing the quality of environmental valuation studies.
- VALUES Methods for integrating ecosystem services into policy, planning, and practice
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- Handbook on Biodiversity Valuation.
- Economic Valuation with Stated Preference Techniques Summary Guide
- An instrument for assessing the quality of environmental valuation studies.

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SUSTAINABLE DEVELOPMENT GOALS

5 GENDER EQUALITY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

14 LIFE BELOW WATER

15 LIFE ON LAND

17 PARTNERSHIPS FOR THE GOALS

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