FAUNA & FLORA INTERNATIONAL

BIODIVERSITY AND ECOSYSTEM SERVICES:

Good Practice Guidance for Oil and Gas Operations in Marine Environments

Fauna & Flora International (FFI) protects threatened species and ecosystems worldwide, choosing solutions that are sustainable, based on sound science and take account of human needs. Founded in 1903, FFI is the world's longest established international conservation body and a registered charity. For more information see: www.fauna-flora.org

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2017

FAUNA & FLORA INTERNATIONAL

Contents

Foreword

Our oceans produce more than half of the oxygen in our atmosphere, as well as absorbing carbon. Over three billion people depend on marine resources for food, and the coastal environment supports the livelihoods of more than 200 million people. Marine habitats make a vital contribution to biodiversity and ecosystem services, but are facing growing threats from pollution and infrastructure development. As energy demands rise, oil and gas companies are focusing increasingly on offshore reserves, placing additional pressure on the marine environment.

Offshore oil and gas developments and their effects on marine biodiversity and ecosystem services are, quite rightly, subject to increasing scrutiny at local, national and international levels, with the result that reputational, operational and financial risk are a growing concern for the oil and gas industry. Until now, however, guidelines on how to apply, monitor and enable industry standards and policy have been conspicuously lacking.

With this in mind, Fauna & Flora International (FFI) has now produced comprehensive guidance that will help oil and gas sector operators to minimise their impact on marine biodiversity and ecosystem services. This is the first guidance document to address the impact of oil and gas extraction specifically in the marine environment, and it will prove invaluable in enabling the industry to operate in an environmentally responsible manner.

Mark Rose, CEO, Fauna & Flora International

Executive Summary

Oceans make up 70% of the Earth's surface and contain rich, largely unexplored underwater domains. Our oceans are home to extraordinary marine life: from the Great Barrier Reef - largest living structure on Earth - to tiny phytoplankton that make up the first layer of the food chain. Oceans play an essential role in the functioning of the planet and provide the conditions that are vital to human lives, livelihoods and wellbeing. Despite their importance, marine ecosystems and the species and services they support are under threat.

Human activities on land and at sea are contributing to the degradation, decline and loss of marine species, habitats and ecosystems and are reducing the ability of the oceans to provide humankind with the resources and services it relies upon. It is into this context of environmental fragility that the extractive energy industry is currently expanding to meet rising global energy demands; currently over a third of oil and gas is extracted from offshore sources and this is expected to increase.

National policy and legislation, lender safeguards and company commitments coupled with growing scrutiny by stakeholders are driving improvements in the mitigation and management of adverse impacts for marine biodiversity and ecosystem services (BES). However, there is limited guidance available to support the practical application and enforcement of existing standards and policies in a marine context.

Fauna & Flora International's (FFI) Good Practice Guidance (GPG) provides pragmatic guidance for identifying, mitigating and managing risks and impacts on BES associated with intertidal through to deep water environments. All stages of the oil and gas project cycle are considered - from seismic surveys to decommissioning – as well as activities or developments directly linked to marine oil and gas operations, including shipping and ports. Note that hydrocarbon spills and onshore developments are dealt with in other existing guidance documents and therefore not addressed here.

A core set of 10 principles serve as the foundation of the GPG and provide a framework for the mitigation and management of impacts. Guidance on impact mitigation is evidence-based and draws on the best available science and practice from leading oil and gas companies, impact assessment practitioners, research institutions, conservation organisations, finance sector experts and marine BES specialists. New and innovative opportunities for impact mitigation are also explored, thereby providing ground-breaking guidance for the sector.

The GPG is divided into seven primary sections, followed by a glossary and supporting appendices. Section 1 provides a concise overview of the GPG - its purpose, scope and structure. Section 2 introduces the 10 core principles that underpin the GPG. These principles are to be applied together in a single, integrated approach:

Principle 1: Do no harm and be proactive in making a positive contribution to BES conservation
Principle 2: Apply the mitigation hierarchy
Principle 3: Apply mitigation planning within a seascape context
Principle 4: Apply an ecosystem approach
Principle 5: Maintain or enhance connectivity
Principle 6: Go beyond compliance
Principle 7: Follow best practices for stakeholder engagement
Principle 8: Ensure a robust baseline for marine BES
Principle 9: Apply a precautionary approach
Principle 10: Share information and data

Section 3 introduces the marine environment from a biodiversity and ecosystem service perspective, highlighting the highly dynamic and connected nature of the marine realm and the complex ecological requirements of marine species. This section considers the role of marine species and their interactions in supporting healthy, functioning ecosystems and the inextricable links between marine biodiversity and ecosystem services. Section 3 sets the ecological context for subsequent sections of the GPG focussed on impact assessment and mitigation.

The rigorous application of the mitigation hierarchy is core to good practice BES management. Section 4 describes potential adverse BES impacts and preventative mitigations (avoidance and minimisation – the first two steps in the mitigation hierarchy) at each phase in the oil and gas project cycle: seismic surveys, exploration drilling, field development, production and operations, and decommissioning. Ports and shipping are also assessed. For each phase of the project cycle, a table identifying activities, potential impacts for BES, and known avoidance and minimisation measures is presented.

For example, a potential impact from both shipping and exploration drilling is the discharge of ballast water which can result in the introduction of non-native (alien) species into the marine environment. Under certain conditions introduced species may establish in their new environment and become invasive with adverse effects for native biodiversity (e.g. through competition for food and space or the introduction of diseases and pathogens) and ecosystem services (e.g. the provision of food if introduced diseases and species negatively affect those species that are important to commercial or subsistence fisheries). A range of mitigation measures is presented, such as conducting ballast water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth in line with regulation B-4 of the Ballast Water Management Convention.

Remedial mitigations, in the form of restoration and offsetting (the last two steps in the mitigation hierarchy) are discussed in Sections 5 and 6 respectively. Restoration techniques can be used to re-establish or improve the ecological integrity and function of ecosystems that have been degraded, damaged or removed by project activity and should be considered early in the project cycle. Section 5 presents restoration in the context of the mitigation hierarchy, defines key principles for effective restoration, outlines the process of restoration planning and identifies opportunities and constraints that are specific to the marine environment. A series of restoration case studies in high value marine habitats (including mangrove, sea grass and coral reef) is presented.

Policy and legislation increasingly requires or makes provision for biodiversity offsets and/or compensation in order to help counteract adverse impacts of development projects. Section 6 focuses on biodiversity offsets: the final step in the mitigation hierarchy and a last resort for addressing residual adverse impacts after all avoidance, minimisation and restoration measures have been applied. This section is designed to complement other existing guidance on biodiversity offsets and focusses specifically on the use of biodiversity offsets for addressing residual adverse impacts on marine ecosystems. Key implications of the GPG's 10 core principles for biodiversity offsets are considered and a further four principles specific to biodiversity offsets introduced:

Principle 11: Limits to offsets.
Principle 12: Offsets deliver outcomes for biodiversity that are additional
Principle 13: Offsets support long-term durable outcomes
Principle 14: Ecological equivalence between biodiversity losses and gains is maximised

The main steps in a good offset process are summarised, potential options and activities in a marine context highlighted, and a selection of case studies presented. Readers are directed to other relevant resources for further information and detailed guidance. Section 7 explores specific considerations for the Monitoring and Evaluation (M&E) of BES including how to identify M&E objectives and indicators, how to plan a monitoring programme, and methods for assessing BES in the field..

The GPG is an essential reference for oil and gas operators, particularly those located in marine environments with high biodiversity value, where there are operational and stakeholder dependencies on ecosystem services, and where measures to avoid, minimise, restore and offset for impacts on BES are being applied to achieve no net loss or net gain outcomes. The GPG is a valuable resource for industry professionals, impact assessment practitioners, BES specialists, policy makers, regulators, financial institutions and civil society groups involved with oil and gas sector interests in the marine environment.

1 Introducing the Good Practice Guidance

Section 1 presents the purpose and scope of this Good Practice Guidance document. By way of context, the global importance of marine ecosystems for climate regulation, biodiversity and value to people is explored. The purpose of this GPG is to provide pragmatic advice to practitioners working with marine oil and gas operations to help them identify, mitigate and manage impacts to BES. The business case for using this GPG is explored, including legal compliance, lender requirements and company reputation. Finally, this section concludes with a summary of those topics covered by this GPG, and those that have been excluded.


Credit: Gus Parker-Jurd

1.1. The global importance of marine ecosystems

Over 70 % of the surface of the Earth and more than 95 % of the volume of habitable space is ocean. Oceans contain rich, largely unexplored domains extending from the sea surface to the seabed and to extreme depths of over 10 kilometres. Oceans are biologically diverse and are estimated to be home to 80% of the world's biodiversity: around 230,000 species of marine plants and animals have been scientifically described. Yet this known biodiversity only represents a small fraction of the number of species that are likely to exist[1].

There is growing appreciation of the essential role that oceans play in the functioning of the planet and delivery of vital ecosystem services (see Box 1). Oceans and seas contain the bulk of all global water, process essential gases, remove carbon dioxide and produce over 50% of oxygen in the atmosphere[2]. They also play an important role in the global climate through the transfer of heat from tropics to poles[3] and provide the conditions that are vital to human lives, livelihoods and wellbeing. For example, the coastal environment provides an essential food source for over three billion people and supports the livelihoods of over 200 million people around the globe[4]. It is the source of many vital products such as medicines and provides essential services including storm defence and flood protection.

Despite their importance, the oceans contain the least explored places on Earth: the deep sea remains largely unknown[5]. While the ocean floor has been mapped to a 5 km resolution, only 15% has been mapped in greater detail using sonar[6]. Ocean are also the least protected; only about 2.9% of coastal and marine areas and less than 0.2% of the high seas are formally protected. Nevertheless, our knowledge of the marine realm is growing: new species and critical habitats are being discovered every day, with discovery rates remaining high in the deep sea[5]. Our understanding of the complex biophysical interactions and ecological processes that support marine communities and ecosystems is also continually evolving.

Yet marine ecosystems and the species and services they support are under threat both from direct uses (e.g. recreational and commercial fishing, aquaculture, recreation, extraction and transportation of oil and gas, shipping) and from upstream or upwind activities (e.g. land use change and habitat loss from agriculture, forestry, transportation, manufacturing, energy generation). Invasive species and climate change are further driving ecosystem change. These cumulative pressures are contributing to an unparalleled rate of regional extinctions of important marine habitats, such as mangroves and seagrass meadows, and localised loss of entire marine ecosystems, such as coral reefs. The number of marine species listed as vulnerable, endangered or critically endangered on the International Union for Conservation of Nature (IUCN) Red List also continues to rise[7] whilst overfishing, pollution, climate change and habitat loss have reduced the ability of the oceans to provide humankind with the resources and services it relies upon[8]. It is into this context of environmental fragility that the extractive energy industry is currently expanding.

Box 1. Ecosystem Services

Ecosystems provide a vast array of benefits that contribute to making human life both possible and worth living. These benefits – termed Ecosystem Services – are generally classified as:

- Provisioning services – goods or products obtained from ecosystems such as biological raw materials (e.g. limestone), food (fish, octopus, seaweed etc.) and shelter (e.g. mangrove poles)
- Regulating services - benefits obtained from the regulation of ecosystem processes such as the regulation of floods and climate, and waste attenuation.
- Cultural services - benefits people obtain from ecosystems such as recreation, spiritual enrichment, cognitive development, reflection, and sense of place.
- Supporting services - natural processes that maintain the other services such as primary production and nutrient cycling.

Credit: Pippa Howard

1.2. The purpose of this Good Practice Guidance

National policy and legislation, lender standards and requirements, and the increasing pressure for companies to demonstrate Corporate Social Responsibility and secure a social licence to operate are driving commitments to good environmental practice among leading oil and gas companies (see Box 2). However, guidance to support the application, monitoring and enforcement of existing standards and policies in a marine context is limited.

This Good Practice Guidance (GPG) provides pragmatic guidance to help practitioners working with oil and gas operations in marine environments to identify, mitigate, and manage impacts to biodiversity and ecosystem services (BES). The guidance is designed to be applicable to all oil and gas operations, but will be particularly useful for those operations located in sensitive marine environments and where the mitigation hierarchy is being applied to avoid, minimise, restore and, where appropriate and possible, offset impacts for BES to achieve a goal of no net loss (NNL) for biodiversity, or a net gain.

This guidance covers both biodiversity and ecosystem services and recommends an integrated approach to identifying potential risks and impacts for BES and appropriate mitigation and management options. This dual focus responds to a) a growing body of evidence confirming the inextricable links between biodiversity and ecosystem services in the marine environment, b) acknowledgement that early integration of ecosystem services into biodiversity and social studies leads to stronger results, and is more efficient and c) the need and opportunity for mitigations to deliver multiple benefits for marine BES.

This GPG introduces 10 good practice principles that should be applied when mitigating and managing risks and impacts for marine BES, supported by detailed guidance where applicable (e.g. for developing a BES baseline). The guidance enables the identification of potential impacts to marine BES at all stages of the oil and gas project cycle, from exploration to decommissioning including impacts from activities or developments directly linked to marine oil and gas operations, such as shipping and ports. For each impact, the guidance helps users to identify specific mitigation options. Mitigations are presented through the framework of the mitigation hierarchy, to ensure a logical and effective approach to protecting and conserving BES[9]. The focus is primarily upon avoidance and minimisation of impacts as the most efficient, straightforward and certain means of mitigation. Guidance on marine restoration and biodiversity offsetting is also provided, though recognising these approaches may be costlier and associated with greater risk and uncertainty. Reference is made to case studies wherever possible.

Box 2. The business case for avoiding and mitigating impacts to marine BES

Already more than one third of the oil and gas worldwide is extracted from offshore sources and this figure is expected to increase[1]. Given the importance and fragility of marine ecosystems, and the suite of threats facing them, it is essential that that risks and impacts from development projects are avoided, mitigated and managed. The business case for managing marine BES may vary with context, company and geography. Some of the key drivers are outlined below:

Legal compliance: The number of countries that have enacted biodiversity policies relating to no net loss (NNL) and net gain for biodiversity is growing. NNL and net gain policies will typically require or encourage adherence to the mitigation hierarchy (i.e. to first avoid, minimise and then restore impacts for biodiversity on-site and, where adverse impacts still remain to offset and/or compensate for those impacts).

Lender requirements: Many International Finance Institutions (IFI) have developed environmental and social safeguards to improve sustainability outcomes of their investments and manage environmental and social risk. Clients in receipt of financing are required to comply with the standards and procedures set out in the safeguards whilst others have voluntarily adopted the safeguards and standards of leading IFIs to demonstrate good international industry practice for BES risk management.

Corporate commitments: Growing recognition of the business case for managing impacts to biodiversity has driven corporate commitments to no net loss (NNL) and net gain[12] in the extractives sector, and across the infrastructure, agriculture, forestry and retail sectors. These commitments are usually biodiversity focused, yet their implementation may also benefit ecosystem services.

Company reputation: As exploitation of marine resources continues to rise, so too does public awareness about the importance of the marine environment for BES and the declining state of the world's oceans. Recent major events such as the Deepwater Horizon spill in the Gulf of Mexico have led to increasing scrutiny of marine developments across a variety of sectors at local, national and international levels. For the oil and gas sector, operations in the marine environment face increasing reputational, operational and financing risks, which are exacerbated when operating in areas of high BES value, and where working at the edge of current technologies in challenging environments.

Cost of environmental reparation: The implications of poor environmental performance are well recognised, including delays to business activity, loss of access to market, long-lasting reputational damage and/or costly clean up or compensation payments. Leading oil and gas companies therefore seek to integrate BES considerations into their business practices and operations to minimise risks and maximise opportunities for BES conservation[12].

Access to resources: The ability to access new resources may be improved by a sound environmental track record. Demonstrating responsible environmental practices may improve access to land, seabed and marine resources, and may translate to an improved share price.

Maintaining ecosystem services makes good business sense: The natural environment provides essential services that benefit people and industry alike, including the regulation of air quality and climate, erosion control and waste treatment and the provision of fresh water, food and energy. In any given location, there will be dependencies on these ecosystem services – both by the operation and by the communities living in and around the project area. Marine oil and gas operations depend on a range of ecosystem services to support operational activities and to manage environmental and social risks, for example, dilution and bio-remediation support the removal of effluent in the wider marine ecosystem. The degradation and loss of ecosystem services can pose operational, financial and reputational risks to project sustainability. Maintaining these ecosystem service values therefore makes good business sense.

Given the downward trajectory of BES globally, operating to best available technology and making a commitment to protect biodiversity and safeguard the supply of ecosystem services are, quite simply, moral imperatives.

1.3. Who should use the GPG

The GPG is designed to support oil and gas industry professionals, Environmental and Social Impact Assessment (ESIA) practitioners, BES specialists, regulators, financial institutions and civil society groups working with the oil and gas industry to adopt and deliver good practice in marine environmental stewardship through:

- the identification and prioritisation of marine BES in a range of marine environments including coastal, offshore, outer continental shelf, oceanic and deep-water environments, often dealing with limited information on BES;
- the determination of impacts to marine BES for a variety of activities at each stage of the oil and gas project cycle;
- the identification of pragmatic and effective mitigations for identified impacts using the framework of the mitigation hierarchy;
- the development of effective monitoring and evaluation; and
- the integration of stakeholder priorities into marine BES management planning.

For the purpose of this GPG we have defined 'good practice' as policies, approaches and techniques that have proven to be effective in the realisation of desired outcomes (i.e. to avoid and minimise adverse impacts on BES). Good practice applies to industry, government and/or civil society actions that are considered by marine BES experts and impact assessment practitioners to effectively address a specific impact. Furthermore, this GPG identifies emerging mitigations which may not be field tested to the same level, yet represent an advance in technology or approach and help to further our knowledge of impact mitigation in the ocean. Such approaches are considered 'aspirational'.

1.4. Scope and structure

This document is structured as follows:

- Section 2 introduces 10 good practice principles that are central to the GPG.
- Section 3 introduces the marine environment from a BES perspective and highlights the complex relationship between biodiversity and ecosystem services.
- Section 4 concentrates on preventative impacts and mitigation measures for each stage of the oil and gas project cycle. Key activities are identified, and their potential impacts upon marine BES are determined using the best available evidence. Preventative mitigations designed to avoid and minimise impacts are described. Case studies are used to illustrate mitigations where appropriate.
- In Sections 5 and 6, the remedial mitigations of restoration and offsetting are considered. These mitigations seek to compensate unavoidable damage to BES.
- Section 7 outlines approaches to effective monitoring and evaluation of marine BES change including the importance of long-term auditing, developing suitable targets and indicators, and understanding thresholds of change.
- A series of appendices providing greater detail on a range of BES issues, including how to conduct a BES baseline study, examples of lender standards relating to BES and a discussion of no net loss and net gain targets.

The following topics are not covered by this Guidance document:

- Hydrocarbon spills. The focus of this document is upon routine operations which have predictable impacts, rather than sporadic or accidental events which are often dictated by local conditions. Oil spill preparedness is often mandated by law in many regions. This field of specialisation lies outside of the scope of this guidance, but is well catered for elsewhere[10,11].
- Onshore developments, such as Liquefied Natural Gas (LNG) processing plants, staff facilities, workshops and supporting infrastructure. These facilities are judged to impact terrestrial habitats to a greater degree than marine habitats and should be dealt with through existing guidance for terrestrial BES[9].
- Global coverage. While this document has been designed to provide globally applicable guidance, specific considerations for the oil and gas industry in particular geographic contexts (e.g. in the Arctic) are not covered and additional guidance should be sought.
- Climate change. The oceans play a key role in climate regulation, and in turn are significantly impacted by increasing global termperatures. Given the enormity of the topic, the guidance does not provide a comprehensive review of the subject and its implications in mitigation planning. Readers are pointed to other sources such as the Ocean and Climate Platform, NOAA and IPIECA for further information.

Credit: Pippa Howard/FFI

This GPG focuses on identifying and managing the negative impacts that marine oil and gas operations can have on marine BES. However, it is recognised that oil and gas operations can too have positive impacts on BES, for example the provision of artificial habitats supporting fish or a hard substrate upon which benthic biota are able to establish. In some circumstances artificial structures can emulate the functions of a natural reef such as protecting, regenerating, concentrating and/or enhancing populations of living marine resources. Furthermore, scientific studies undertaken in support of oil and gas projects have made an important contribution to our knowledge of marine BES with significant and widespread benefits. Such benefits are acknowledged here but are not considered further in this document..

1.5. Resources and referencing

This GPG takes an evidence-based approach, using the best available science and case studies from industry to provide robust yet pragmatic guidance for identifying and mitigating BES risks in the marine oil and gas sector. It draws upon the operational experiences of leading oil and gas companies, research organisations, NGOs, experts from the finance sector and marine biodiversity specialists. Where good practice already exists, it is summarised here and the full reference is provided. Links can be found throughout the text which lead to further information in the appendices, or to external resources.

A Glossary of technical terms draws upon the UNEP-WCMC Biodiversity A to Z website for definition of technical terms relating to BES. For terms relating to the oil and gas industry we refer readers to the SBM Offshore Glossary of Terms.

External material referred to in this document is marked with a number in superscript[1] which links directly to the full citation in the References listed at the end of the document. Footnotes are used to present additional information and are marked with a roman numeral in superscript[i].

2 Principles

This Guidance is based on a core set of principles. These 10 principles serve as a framework to help all those involved in the marine oil and gas sector to mitigate and manage risks and impacts to marine BES and to achieve the best outcomes for marine BES. The principles must be applied together and as one integrated approach.

Principle 1: Do no harm and be proactive in making a positive contribution to BES conservation
Principle 2: Apply the mitigation hierarchy
Principle 3: Apply mitigation planning within a seascape context
Principle 4: Apply an ecosystem approach
Principle 5: Maintain or enhance connectivity
Principle 6: Go beyond compliance
Principle 7: Follow best practices for stakeholder engagement
Principle 8: Ensure a robust baseline for marine BES
Principle 9: Apply a precautionary approach
Principle 10: Share information and data

Principle 1: Do no harm and be proactive in making a positive contribution to BES conservation

Companies should maximise efforts to prevent harm to BES and strive to make a positive contribution towards seascape conservation goals. A growing number of companies have committed to achieving 'no net loss'[12] which aims to counterbalance adverse impacts of a development project or programme by positive actions that restore and conserve biodiversity such that there is no overall reduction in the type, amount or condition of biodiversity[13]. It implies a legacy of no overall harm compared to what would have occurred in the project's absence. Net gain is achieved when there is a positive impact on biodiversity that not only balances but exceeds losses caused by development impacts (see Figure 1).

Principle 2: Apply the mitigation hierarchy

The mitigation hierarchy is a framework involving a series of steps (Figure 1) designed to help users anticipate and take action to limit the negative impacts of development projects including direct, indirect and cumulative impacts. It can be applied to both biodiversity and ecosystem services.

Figure 1: Biodiversity impacts and the mitigation hierarchy.

Avoidance is the first and most important step in the sequence and requires that potential adverse impacts on BES are anticipated and prevented before impacts occur. Avoidance is the most ecologically effective step through which large gains for BES are possible with higher certainty of success. The loss of BES should always be avoided where they cannot be substituted or replaced elsewhere, where there is a high degree of uncertainty associated with proposed mitigation measures, or where the risk of mitigation failure is high.

After all efforts to avoid adverse impacts have been taken, **minimisation** of impacts should be undertaken through action to reduce the duration, intensity, significance and/or extent of impacts that cannot be completely avoided. Avoidance and minimisation are considered preventative measures.

Where residual adverse impacts remain, the feasibility of ecological **restoration** should be investigated. Restoration is usually carried out on-site and to repair impacts caused (directly or indirectly) by the project. Biodiversity **offsetting** is the last step in the mitigation hierarchy, and may be considered, where appropriate and possible, to counteract significant adverse residual impacts that remain after all avoidance, minimisation and restoration measures have been applied. Restoration and offsets are considered remedial measures and can be complex, expensive and uncertain in outcome[9] (see Sections 5 and 6). To reduce requirements for restoration and offsets, emphasis on the early steps of avoidance and minimisation must be prioritised to the maximum extent practicable[14].

The mitigation hierarchy, as an approach to mitigation planning, can be used as an implementation framework for achieving no overall harm or net gain objectives (Principle 1), supporting seascape level conservation priorities (Principle 3), meeting regulatory and lender requirements and/or achieving internal company standards. It provides a mechanism for measurable conservation outcomes for BES that can be implemented on an appropriate geographic scale (e.g. ecosystem, regional, national, local)[9,14].

Principle 3: Apply mitigation planning within a seascape context

Effective mitigation planning is informed by an understanding of the wider seascape. What are the conservation priorities within the seascape[i]? Who else depends on and influences the seascape? What other developments are operating, planned and anticipated and with what impacts? Is there potential for conflicts, risks and trade-offs among different users and their respective objectives? Seascape-level assessments of conservation priorities and development scenarios should inform project planning, impact avoidance and mitigation wherever possible[15] (Figure 2). They should identify biodiversity values, ecosystem service dependencies, and potential direct, indirect, and cumulative impacts to these. Seascape assessments should be conducted as far in advance of project decisions and investments as possible. In this way, BES values that are too important to lose can be identified and avoided; opportunities for coordination and collaboration in the identification and mitigation of impacts among seascape users can be realised; and actions to compensate or offset residual impacts on BES can be designed to contribute towards seascape level conservation objectives.

Principle 4: Apply an ecosystem approach

The ecosystem approach[16] supports a holistic approach to BES conservation and management and recognises human communities as an integral part of the ecosystem. Therefore, rather than focusing on individual species or habitats in isolation, an ecosystem approach considers land, sea, living resources and people in an integrated and adaptive way. It encourages a better understanding of the way ecosystems function. Taking an ecosystem approach to project development and mitigation planning in the marine environment is crucial given the highly dynamic, complex and interconnected nature of marine ecosystems (see Section 3) and requires:


Credit: Robert Howard/FFI

- an understanding of marine ecosystems including their living (e.g. plant, animal and micro-organism) and non-living components and how they interact over space and time (see Section 3 and Box 4).
- recognition of the relationship between biodiversity and marine ecosystem services and an integrated approach to the assessment and mitigation of impacts for BES.
- the use of best available marine ecological and ecosystem service information and expertise at all stages in project and mitigation planning.
- mitigation and management measures that maintain, restore or enhance marine ecosystem composition, structure and function, and, where appropriate, ecosystem services.

Principle 5: Maintain or enhance connectivity

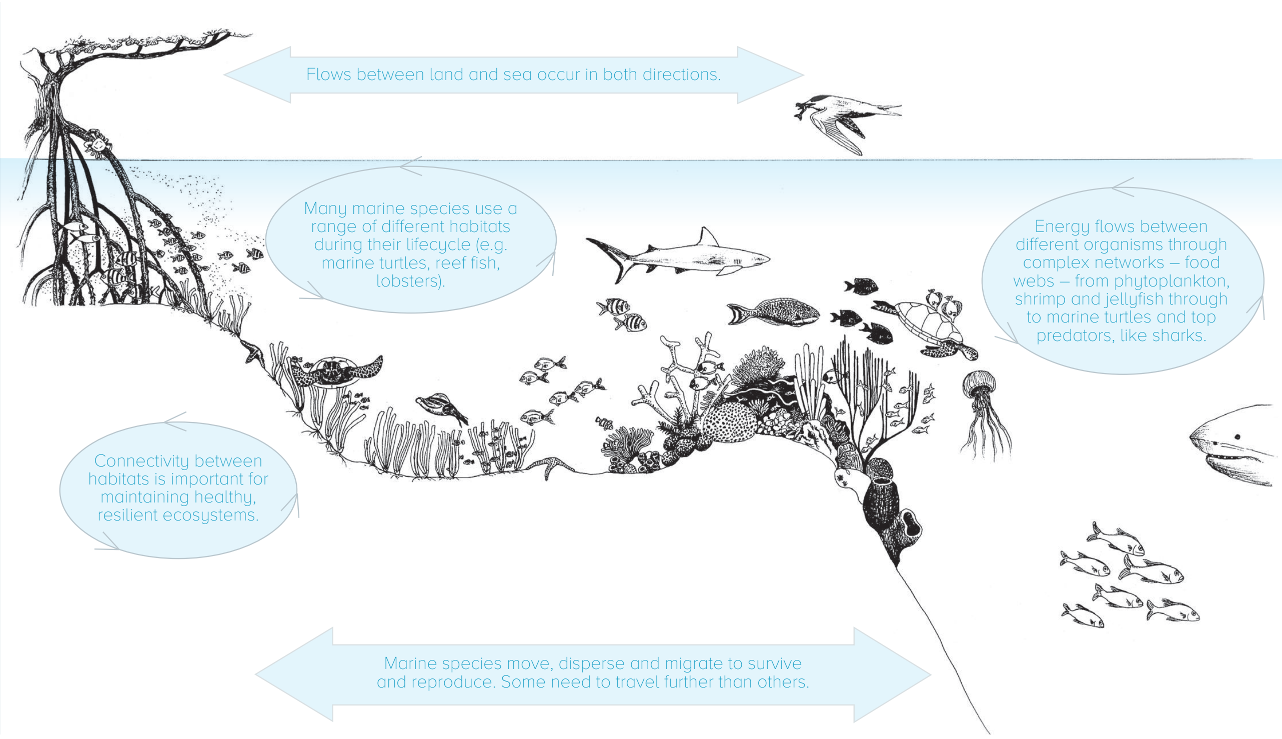
Connectivity is the 'degree to which the land and seascape facilitates or impedes movement among resource patches'[17]. It is described as the fundamental 'circulatory system' for life[18]. Organisms (from plankton to blue whales) and associated abiotic systems (e.g. water and nutrient cycles) don't respect boundaries but need to flow, move, disperse and migrate[19]. Movements occur over a wide range of spatial and temporal scales and many marine species interact with and influence multiple habitats (marine, freshwater and terrestrial) over their lifetime (see Section 3).

Maintaining connectivity is essential for supporting key processes including dispersal and both local movement and seasonal migrations for food, mating and production of offspring. Connectivity is critical in determining ecological relationships, supporting

i As identified through, for example, national biodiversity strategies and plans, species or habitat action plans, coastal and marine conservation management plans, systematic conservation plans.

ecosystem functions and contributing to the resilience of marine ecosystems (i.e. the ability of an ecosystem to absorb shocks, disturbances and long-term changes and continue functioning - see Figure 2). Incorporation of connectivity considerations at all stages in project and mitigation planning is important. All efforts to avoid and minimise disruption to connectivity should be applied to the maximum extent practicable. Opportunities to restore or enhance connectivity (e.g. in the design of biodiversity offsets) should be fully explored.

Figure 2: Conceptual diagram illustrating connectivity among marine habitats and the complex communities they support.



Principle 6: Go beyond compliance

This GPG assumes compliance with all relevant international, transboundary, national and sub-national laws and regulations, recognising these vary greatly from place to place (Appendix 1). It encourages operators to look beyond their compliance commitments and apply good practice with respect to BES in all aspects of development planning and mitigation.

Improvements in policy and legislation in some jurisdictions and the development of environmental and social safeguards or standards by leading international and other private financial institutions have raised the bar for environmental performance (See Appendices 1 and 2 for further discussion). Industry and sector initiatives have also played an important role in driving improvements in practice through development of tools and guidance that is relevant to, or specifically for, the oil and gas sector. Today, a wide range of good practice guidance products are available and increasingly referenced by environmental professionals working in or with the oil and gas industry and financial institutions (see Appendix 3).

Principle 7: Follow best practices for stakeholder engagement

Meaningful and inclusive engagement with stakeholders is fundamental to the management of marine BES. Stakeholder engagement should involve all relevant stakeholders and rights-holders[ii] in a transparent process of risk and impact assessment, decision-making and implementation. This requires the effective communication of information regarding proposed projects and mitigation in a public, timely, and culturally appropriate manner, and documentation and public disclosure of the consultation process and results.

The right of indigenous peoples and other local communities to free, prior and informed consent (FPIC) must be respected regarding projects and mitigation plans and actions (see Box 3). Rights based approaches should be followed in all cases, with

ii Relevant stakeholders include those who may be affected by project development (directly, indirectly and cumulatively), those who may bear the costs of mitigation action and/or may play an important role in delivering mitigation action and monitoring BES outcomes.

respect for legal and customary tenure rights (i.e. the systems that define who can use what resources for how long and under what conditions).

Meaningful stakeholder participation in development and mitigation decision-making processes can increase the likelihood of successful and socially acceptable mitigation plans and support better, more sustainable outcomes. Further information and guidance to support best practice stakeholder engagement and rights-based approaches are available[20,21,22,23,24,25,26,27].

Projects should incorporate the best available scientific and traditional ecological knowledge into planning, decision-making and actions on the ground. Early and ongoing consultation with relevant marine technical specialists (local, regional and international) and traditional ecological knowledge holders will be essential.

Box 3: Free, Prior and Informed Consent (FPIC)[28]

Free, prior and informed consent (FPIC) is the principle that a community has the right to give or withhold its consent to proposed projects that are likely to affect the lands and resources it customarily owns, occupies or otherwise uses. FPIC has been enshrined in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)[29] since 2007 but is increasingly being extended to include the statutory and customary rights of other communities to their lands, territories and resources.

Credit: Pippa Howard

Under FPIC, negotiations between companies, governments or other project proponents and local communities must be **free** from force, intimidation or other pressure. Consent must be sought from communities **prior** to authorisation by other bodies (e.g. government issuing of licenses) and before any activities are undertaken that may affect them. The form of the **consent** will be context specific and should be sought at various stages of a project, rather than as a one-off. Communities must be given sufficient time to decide whether they will agree to the project or not. They need to have a full and accurate understanding of the implications for them and their lands so that they can make an **informed** decision *according to the decision-making process of their choice*.

FPIC is a right. It is not a linear process that ends with the signing of a single binding agreement with a community. FPIC recognises the rights of indigenous and local communities to be treated as the rightful managers of their customary territory and therefore guarantees them a voice in decisions at *every stage* of the planning and implementation of projects that affect them. FPIC should therefore be understood as a *right* that requires an *on-going* process of communication and engagement with consent being sought at key stages in the process.

For more information see: Fauna & Flora International's FPIC advice

Principle 8: Ensure a robust baseline for marine BES

Given the complex, dynamic and interconnected nature of marine ecosystems (see Section 3), the importance of undertaking marine BES baseline studies cannot be underestimated. A marine BES baseline should be developed as early as possible, and at an appropriate scale, scope and depth. This is essential for properly anticipating potential risks, impacts and opportunities and for enabling the rigorous application of the mitigation hierarchy and design of long-term BES management and monitoring measures. The process of establishing a baseline is iterative and must be adaptable to new information (see Figure 3). Over the long-term, thorough baselines are likely to prove cost-effective as they may prevent costly delays and difficulties relating to BES-related issues later in project development. For additional resources and guidance on developing a marine BES baseline see Appendix 4.

Principle 9: Apply a precautionary approach

Our understanding of the marine realm, and especially its biodiversity, is in its infancy and we are only now starting to appreciate the complex interactions between species, habitats and their wider environment (e.g. the influence of nutrients, ocean currents and storm cycles on primary production). Oil and gas developments in the marine environment are therefore faced with considerable uncertainty when determining adverse risks and impacts for marine BES. However, lack of certainty regarding the threat of environmental harm should never be used as an excuse for not taking action to avert that threat. Delaying action until there is compelling evidence of harm will often mean that it is then too costly or impossible to avert the threat[30]. Where there is uncertainty, the threat of environmental damage and the potential for threats to lead to serious or irreversible harm, a precautionary approach must be applied. In practical terms, this means:

- Use of the best information available and meaningful engagement with all relevant stakeholders and rights-holders.
- Development of robust baselines of the appropriate scale, scope and depth (see Principle 8)
- Explicit recognition of uncertainties, gaps in information, and limitations of available methods for detecting and assessing threats.
- Evaluation of different mitigation options and the consequences of various courses of action and inaction; prioritising avoidance and minimisation of potential impacts to the maximum extent practicable.
- Application of well-accepted ways to add contingency when calculating biodiversity losses and gains in order to account for risks, and compensate for the time between losses occurring and gains being fully realised.
- An adaptive management approach involving the monitoring of mitigation and management actions, and evaluation of outcomes.

Figure 3. Generalised steps in the iterative process of establishing a baseline for marine BES.

Principle 10: Share information and data

The marine oil and gas sector has an important role to play in improving regional knowledge and mapping of the marine realm. Baseline studies from the marine oil and gas sector have already significantly increased our understanding of the marine environment and thus have a wider societal value. Information and data should, wherever possible, be made available through publically accessible repositories. Such data submissions constitute an important and positive contribution towards seascape level BES conservation and marine science.

3 Understanding marine ecosystems and biodiversity

This section provides an essential introduction to the marine environment - its dynamic and highly interconnected nature and rich biological diversity. Different types of coastal and oceanic habitats are briefly described and the varied and often complex ecological requirements of marine species considered. The complex network of interactions between species and their environment and the roles that individual species and populations play in maintaining ecosystem function and health are highlighted, and the inextricable links between biodiversity, ecosystem function and ecosystem services are presented. This underlines the need for an integrated and ecosystem based approach to mitigation planning.

Credit: Pippa Howard

3.1. Marine ecosystems

Marine ecosystems are a dynamic complex of living (i.e. plant, animal and micro-organism) communities and their non-living environment, interacting as a functional unit (see Box 4). They are vast, highly complex and interconnected. They are three-dimensional, with oceans being contained in a basin that is determined by the geology of the oceanic and continental crust. Water is in a constant state of motion over multiple spatial and temporal scales - from fractions of millimetres and seconds to thousands of kilometres and tens of thousands of years[2]. Geological, physical and oceanographic forces have shaped ocean basins over millennia, driving the development of underwater landforms (e.g. seamounts, volcanic islands, atolls, submarine canyons) and producing hot and cold mineral-rich waters (e.g. hydrothermal vents, cold water seeps).

The properties of the water form stratified layers, tides, and currents. Upwellings break this stratification by mixing layers and creating vertical and lateral heterogeneity within the ocean biome. Physical factors (e.g. geology, temperature, tides, light availability and geography) play a critical role in determining the distribution of ecosystems in the ocean and the physical and biological processes of oceans are intimately connected. Strong boundary currents, upwelling systems and other complex features such as fronts, eddies, and localised gyres, can be important in driving and defining ecological processes and transition zones for biodiversity (see Box 4).

Box 4: Composition, structure and function and their importance for supporting healthy ecosystems.

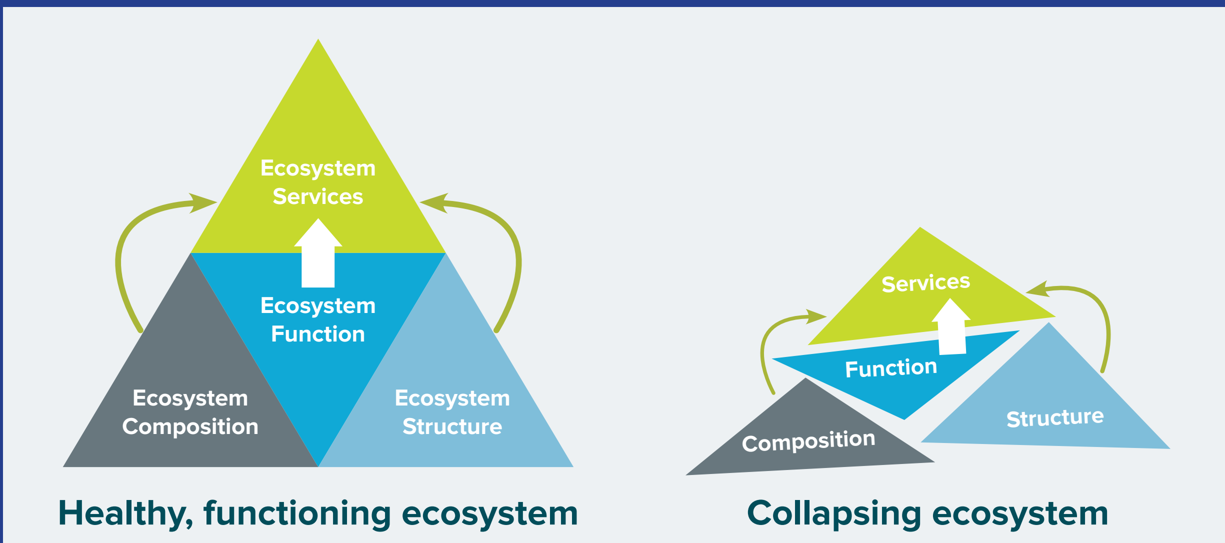
The composition and structure of a marine ecosystem supports its ability to function and provide a range of essential ecosystem services (Figure 4). Composition refers to the identity and variety of an ecological system. It is commonly described through species lists and measured using species richness and diversity indices. Structure refers to the biophysical (i.e. living and non-living) architecture of an an ecosystem, which may be composed of a variety of substrates and species.

Ecosystem functions are described as intrinsic ecosystem characteristics whereby an ecosystem maintains its integrity. They include decomposition, production, nutrient cycling, and fluxes of nutrients and energy. These functions are the result of one or more ecological or evolutionary processes, such as predation, gene flow, natural disturbance and species adaptation over time, as well as abiotic processes such as the hydrological cycle.

Where habitat is converted, degraded and fragmented, where populations are reduced and fragmented, and when keystone and other highly interactive species are lost from a community, this adversely affects ecosystem structure and composition, the resilience of the ecosystem (i.e. its capacity to absorb stresses and continue functioning) is weakened, ecosystem functions are disrupted and the delivery of ecosystem services is compromised (Figure 4).

Ecosystem structure, composition and function all operate at multiple scales and incorporate spatial and temporal dynamics. Consequently, it may be necessary to consider them at different scales such as a region, seascape and/or ecosystem.

Figure 4: A thriving ecosystem (left) with good composition and structure that supports ecosystem function and the provision of essential ecosystem services for people. A collapsing ecosystem (right) in which habitats have been altered and degraded and ecosystem composition, structure and function has been compromised.



Many ocean features, processes, communities and ecosystems are only recently being discovered and described (see, for example, Boxes 5 and 6).

Box 5: New discoveries: Coral reef uncovered at the mouth of the Amazon

The recent discovery of an extensive coral reef close to the mouth of the Amazon River has taken marine scientists and policy makers alike by surprise[31], highlighting our limited knowledge of marine ecology even in shallow coastal waters. The reef is 960km long, stretching from French Guiana to Brazil, and covers an area of 9,300km^2 in waters of 30-120m depth[32]. What has surprised scientists the most is the position of the reef at the mouth of the Amazon river, where fresh water and sediments create a muddy plume for hundreds of kilometres. These conditions are not considered ideal for shallow water corals, which tend to thrive in clear, salty, sunlit conditions. Indeed, many reef systems have gaps where large rivers flow into the sea[31].

Credit: Greenpeace

The Amazon reef's biodiversity is relatively low as compared to other tropical reef systems, containing a moderate diversity of algae, sponges, corals and reef fishes. However, the assemblages of species show significant differences between the northern, central and southern sections of the reef in response to the different levels of sedimentation[32], salinity and light. The north section is shielded from sunlight by the muddy plume more than half of the year and is dominated by sponges and carnivorous fish. The southern section is only covered by the plume three months of the year, is more conducive to photosynthesis, and contains a greater diversity of corals, including staghorns[33].

This marginal reef has been shaped by conditions quite different from archetypal coral reef. Such adaptations to high sediment and variable salinity may provide insights into how coral reefs may cope with changing marine conditions globally. The reef supports a thriving fishing industry of small and medium sized boats which fish primarily for red snapper and spiny lobster, and is very important for communities living at the mouth of the Amazon[32].

The Amazon river mouth is an area of intensive oil and gas operation, with 80 blocks having been granted and a further 20 blocks already producing oil. It is not known how oil and gas operations may affect the reef system. The discovery of such a large reef system in shallow waters underlines the gaps in our knowledge of marine ecosystems and emphasises the importance of thorough baseline studies.

The interface between the ocean and land is also highly dynamic and constitutes a major ecosystem that occupies about 8% of the Earth's surface. Both marine and terrestrial sides of the coastal zone are relatively productive in terms of the abundance of biomass generation.

Marine and terrestrial systems interact extensively, with flows occurring in both directions. Terrestrial systems export nutrients and organic matter (e.g. sediments, nutrients, wastes) to coastal oceans mainly through river systems but energy and biomass from productive marine systems also flow into terrestrial islands and coastal systems in a variety of ways. For example, marine nutrients from marine algae and detritus, sea bird guano and sea foam fertilise plants, increase productivity and affect the food web. Marine prey and detritus (e.g. pinnipeds, marine turtles and sea birds) can also subsidise inputs from terrestrial systems to support dense populations of diverse coastal consumers, alter the communities of entire islands, and influence population dynamics and behavioural ecology of some terrestrial species. Marine inputs in terrestrial systems not only affect recipient species but percolate through the food web to govern the dynamics of most species on islands and in coastal areas.

Box 6: The Mozambique Channel in the Indian Ocean and its unique and extraordinary BES[34]

The Mozambique Channel is bounded by the oldest coastlines and seabed of the Indian Ocean; however the oceanography and globally unique eddy dynamics of the Mozambique Channel were unknown until relatively recently. They contribute to the western boundary currents in the Indian Ocean that play an important role in the global conveyor belt of ocean circulation which helps regulate the global climate system.

Credit: Pippa Howard/FFI

The geology and oceanography of the channel shape the ecosystem dynamics and habitats of the channel whilst the eddies and currents influence the channel and all levels of biological function. Unique eddy dynamics and upwelling on the Madagascar Plateau contribute to the highly connected and productive shallow benthic and pelagic marine communities, including coral reefs and plankton, and influence the behaviour and activity of large fish, marine turtles, sea birds and marine mammals. The channel is critically important for larval supply to downstream reefs and thus for resilience of species and ecosystems along the east African coast.

The Mozambique channel is a mosaic of rich ecosystems: coral reefs, coral banks, mangroves, and seagrasses, and volcanic, karst or coral islands and islets, bays. The coral reefs in the northern part of the channel harbour some of the highest diversity of corals in the region, as well as restricted range molluscs and fish species. Half the breeding sea birds of the Western Indian Ocean breed in the Mozambique Channel and it is one of most productive of the five main foraging grounds for sea birds in the Western Indian Ocean. Turtle migration patterns criss-cross the channel and cetaceans use the Mozambique Channel as prime wintering, feeding and nursing grounds.

The full biological consequences of the Northern Mozambique Channel are not yet known, but its eddies and currents are likely to be important for the species and ecosystem processes and for fisheries and other ecosystem services of the entire Western Indian Ocean.

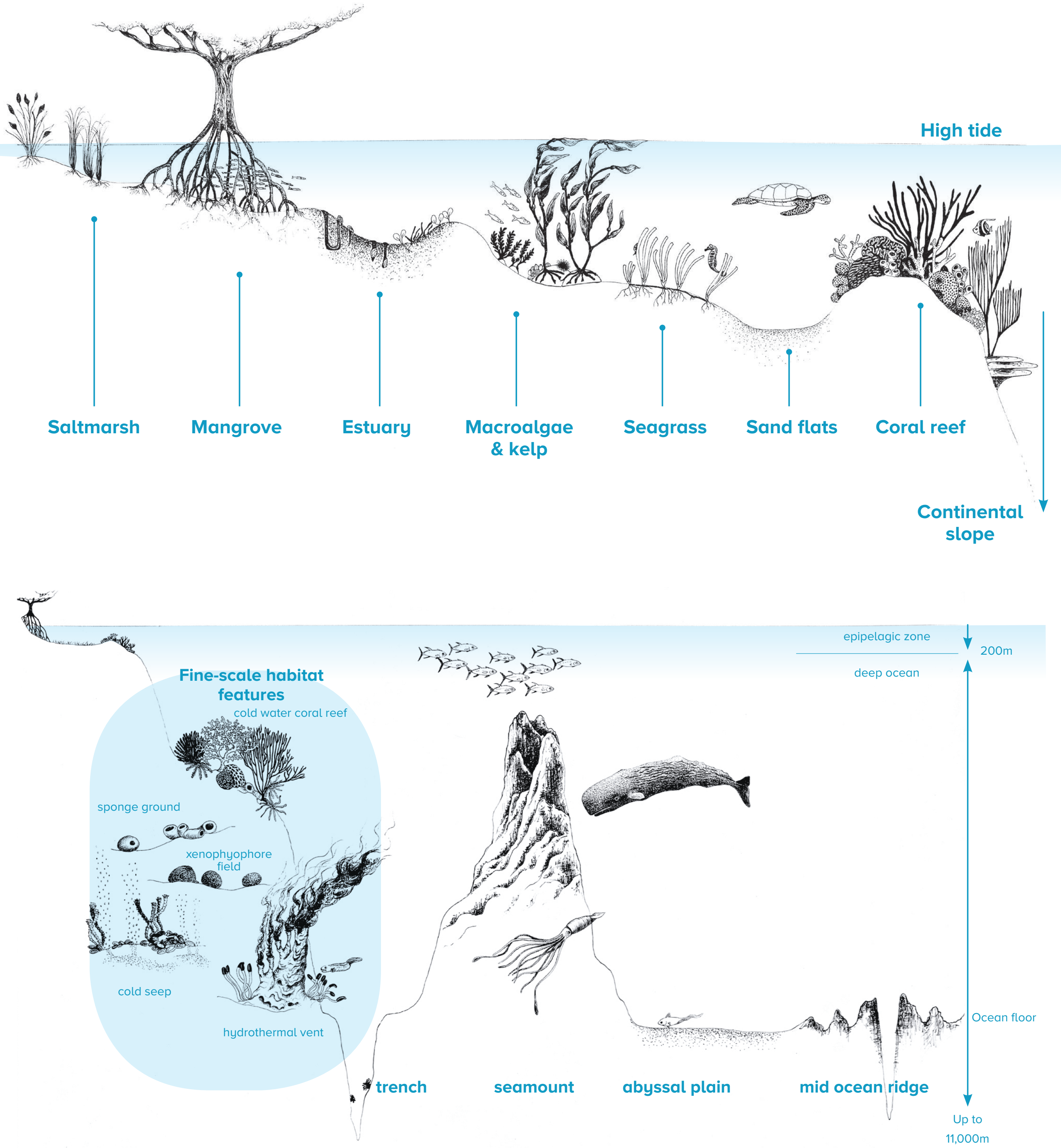
3.2. Marine habitats: a window into marine system complexity

'Habitat' means the place or type of site where an organism or population naturally occurs[38] . The presence, survival and reproduction of a population will depend on the suite of resources (food, shelter) and environmental conditions (abiotic and biotic) provided by the habitat[39].

The identification and delineation of marine habitat types can help us start to understand complexity in the marine environment. For example, habitat types can often represent patterns of biodiversity values, underpin ecosystem functions and support the provision of ecosystem services.

For the purpose of this Guidance, habitat types are a simplified version of the IUCN global standard of marine habitat classification[40]. Here we describe these habitat types and some of the biodiversity values, ecosystem functions and services that different habitat types are associated. Also see Appendix 4.

Figure 5: Conceptual diagram illustrating select coastal and near-shore benthic habitats (top image); and oceanic habitats (e.g. trenches, seamounts, abyssal plain, ridges) and associated finer scale habitat features (e.g. cold-water coral reefs, cold seeps, hydrothermal vents) which can be found at variable depths in the ocean (bottom image).



Coastal habitats

Coastal habitats are found in the area that extends from the high tide mark on the shoreline out to the edge of the continental shelf, in waters less than 200 metres in depth (Figure 5). Coastal habitats in the inter-tidal zone may include coastal salt marshes, tidal mud flats, estuaries (Box 7), sandy beaches, mangroves, gravel/cobble beaches and rocky shores. Near-shore benthic (bottom) habitats may include bare mud/sand flats, low and high profile hard substrate, seagrass beds (Box 8), macro-algae forests, kelp and coral reefs (Box 9).

Box 7: Estuarine habitats

An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with salt water from the ocean. Estuaries and the lands surrounding them are places of transition from land to sea and freshwater to salt water[1]. Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such land forms as barrier islands or peninsulas. Estuarine environments are among the most productive on Earth, creating more organic matter each year than comparably-sized areas of forest, grassland or agricultural land[1]. The tidal, sheltered waters of estuaries also support unique communities of plants and animals that are adapted for life at the margin of the sea.

Credit: Pippa Howard/FFI

Estuarine habitats support a wide variety of ecosystem services. For example, habitats associated with estuaries, such as salt marshes and mangrove forests, act like enormous filters. As water flows through a salt marsh, marsh grasses and peat (a spongy matrix of live roots, decomposing organic material, and soil) filter pollutants such as herbicides, pesticides, and heavy metals out of the water, as well as excess sediments and nutrients[41]. Estuaries and their surrounding wetlands are also buffer zones. They stabilise shorelines and protect coastal areas, inland habitats and human communities from floods and storm surges from hurricanes. When flooding does occur, estuaries often act like huge sponges, soaking up the excess water. Estuarine habitats also protect streams, river channels and coastal shores from excessive erosion caused by wind, water and ice.

Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and salt marshes[1], sandy beaches, mud and sand flats, rocky shores, oyster reefs, mangrove forests, and seagrass beds.

Box 8: Seagrass beds

Credit: Pippa Howard

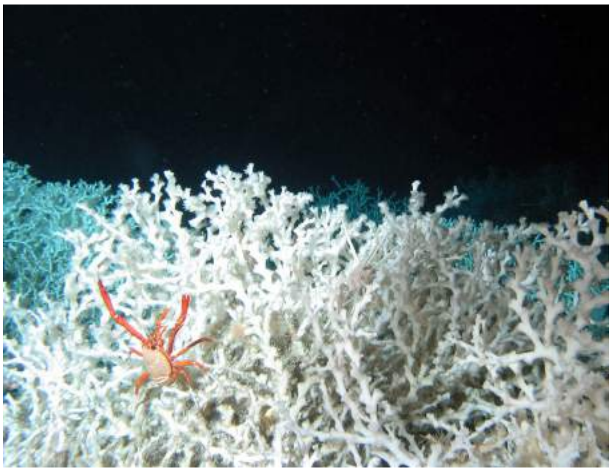
Seagrasses are marine flowering plants of some 58 known species. Seagrass species distribution datasets are produced through the IUCN Red List[42] process. Seagrass beds cover approximately 0.1–0.2% of the global ocean floor in both estuarine and inshore coastal environments[43]. Seagrass beds are a highly productive ecosystem and provide important ecological and economic functions including nursery habitat for fisheries[44] and acting to prevent coastal erosion and siltation of coral reefs[45,46,47]. Moreover, seagrass habitats provide recreational benefits to society and tourism industries[48]. Loss of seagrass habitat from direct and indirect human impacts is estimated to be 33,000 km^2 globally over the last two decades[49]. The primary cause of degradation and loss is from direct habitat disturbance or removal, and from a reduction in water clarity, both through increased turbidity and increased nutrient loading[50,51,52].

Oceanic habitats

Open ocean habitats are found in the deep ocean beyond the edge of the continental shelf, in waters of 200 – 11,000 metres in depth (Figure 5). Oceanic habitats can be divided into pelagic and benthic habitats. Pelagic habitats are found near the surface or in the open water column, away from the bottom of the ocean. Pelagic habitats are dynamic, always shifting depending on what ocean currents are doing. Benthic habitats are near or on the bottom of the ocean. The deep ocean covers more than 87 percent of the ocean floor[53].

Oceanic habitats include vast abyssal plains, seamounts, mid-ocean ridges, trenches, canyons, cold seeps, hydrothermal vents and deep water coral systems (Box 10). Deep sea benthic habitats are generally poorly documented and understood. However, studies suggest that deep sea biodiversity is essential for the sustainable functioning of the entire ocean[53].

Credit: Daniel Jones



Credit: Daniel Jones

Box 9: Coral reefs

Coral reef ecosystems are generally associated with coastal habitats in shallow tropical waters. Deep water corals are found in deep sea environments[54]. Coral reef ecosystems support high levels of unique biodiversity and provide significant habitat for fisheries, provide storm protection and generate additional socioeconomic benefits through tourism. It's estimated that 850 million people live within 100 km of a coral reef and that up to half a billion people depend economically on coral reefs ecosystems[55].

There is increasing concern and a broad scientific consensus that coral reef ecosystems are being rapidly degraded[56]. Major anthropogenic impacts include mortality and reduced growth of the reef-building corals due to their high sensitivity to rising seawater temperatures, ocean acidification, water pollution from terrestrial runoff and dredging, destructive fishing, overfishing, and coastal development[57]. Understanding such baseline trends in habitat condition and extent is important when determining likely direct, indirect and cumulative impacts of marine oil and gas developments.

Box 10: Sensitive habitats in the deep ocean

The deep ocean (>200m) covers around 63% of the area of the Earth[58]. It contains many different benthic habitats defined on multiple scales, from major morphological features[59] to differing sedimentary habitats[60]. Of the major morphological features, seamounts and submarine canyons are usually those identified as being potentially sensitive habitats[58]. Superimposed on the major habitats are finer-scale features caused by local processes, such as fluid flow (e.g. cold-seeps, methane-derived authigenic carbonate, pockmarks, hydrothermal vents), faulting (e.g. graben / horst structures), sediment transport (e.g. barchan dunes, sand waves) and local biology (e.g. xenophyophore fields, sponge grounds, cold-water coral reefs)[58]. These harbour different species, have different extents in the global ocean and likely vary significantly in their sensitivity. Pelagic habitats and communities are commonly not considered in impact assessments, but nevertheless can be divided into habitats and may be sensitive to disturbance. There is little information upon which to determine the sensitivities of most deep-sea habitats, but it can be assumed that habitats with limited extent are particularly sensitive.

Credit: Five Oceans and World Ocean Review

Deep ocean conditions are characterised by low energy availability, with both low temperatures (with a few exceptions, such as the Mediterranean and Red Sea) and low food supply, constant conditions, lots of unknown species and typically low levels of disturbance. As a result, metabolic rates are slow, species tend to be long lived and are poorly adapted for rapidly responding to environmental changes. Adopting a precautionary approach, it should be assumed that all deep ocean habitats are sensitive.

3.3. Marine species and their interactions

Marine ecosystems are highly diverse. Some are very productive within concentrated areas (e.g. near-shore systems such as estuaries, salt marshes, and mangrove forests). Others, such as the abyssal plain, are spatially heterogeneous yet contain one of the largest reservoirs of biodiversity on Earth, spread over a vast area[61]. Some, like the deep sea, are in constant darkness where photosynthesis cannot occur whilst others, like rocky shores, regularly experience extreme changes in temperature, light availability and oxygen levels. The species and communities these ecosystems support are highly adapted to the physical conditions of the ecosystem in which they live. For example, species that live in the deep sea face pressures up to one thousand times greater than the shallow oceans, and have adapted to these conditions with pressure-resistant biomolecules.

Many marine organisms spend at least part of their life cycle in the water column and are subject to transport by currents, whether passively suspended or swimming actively. For both invertebrates and fish, passive transport usually occurs during larval development and is typically a one-way transport in ocean currents. Many other species are highly mobile and wide ranging such as marine turtles, cetaceans, sea birds and some large fish, such as tuna and sharks[62]. They swim vast distances in seasonal or annual migrations, usually coordinated with current systems to reduce energetic costs.

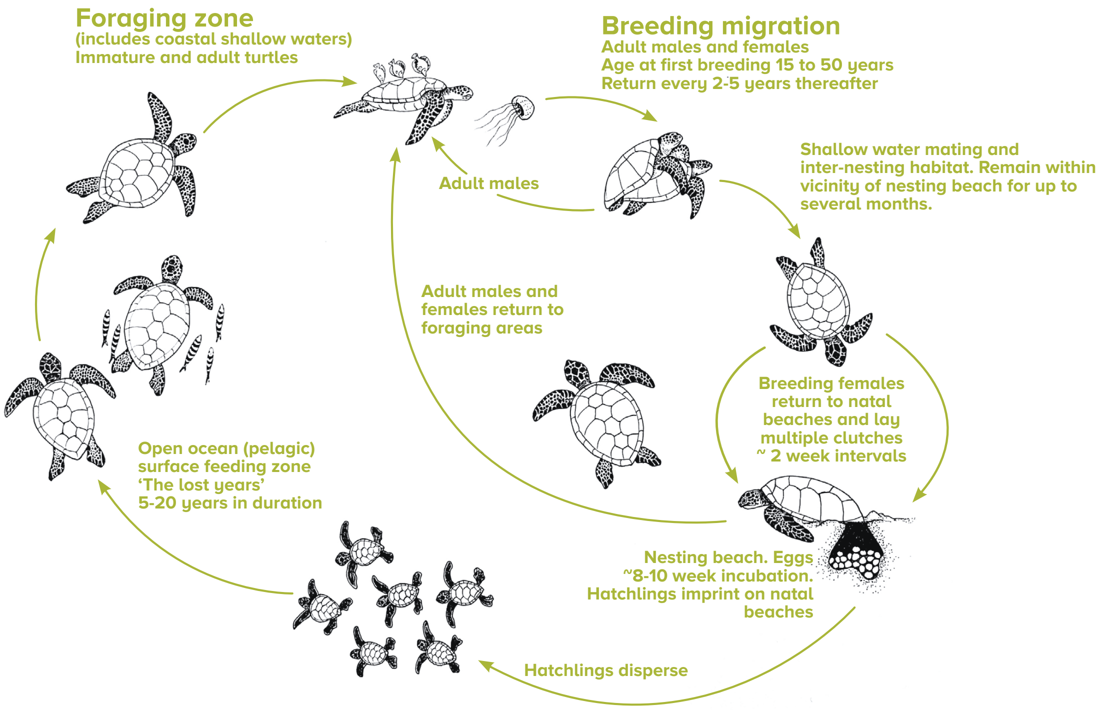
Many marine species will use a range of habitats at different points in their life histories (Figure 6) and for some species this will include terrestrial and/or freshwater habitats as well as marine (e.g. marine turtles, pinnipeds, sea birds and some fish). This means that individual species and populations both depend on and can play a key role in the functioning of numerous ecosystems throughout their lifetime (Figure 6). For example, the return of spawning salmon to Pacific Northwest streams represents a tremendous annual input of marine nutrients to freshwater ecosystems. Where these species are adversely impacted or lost there will likely be ecosystem-level ramifications[63]. Connectivity plays a critical role in ecological relationships in the marine realm and in sustaining species at different phases of their life cycle.

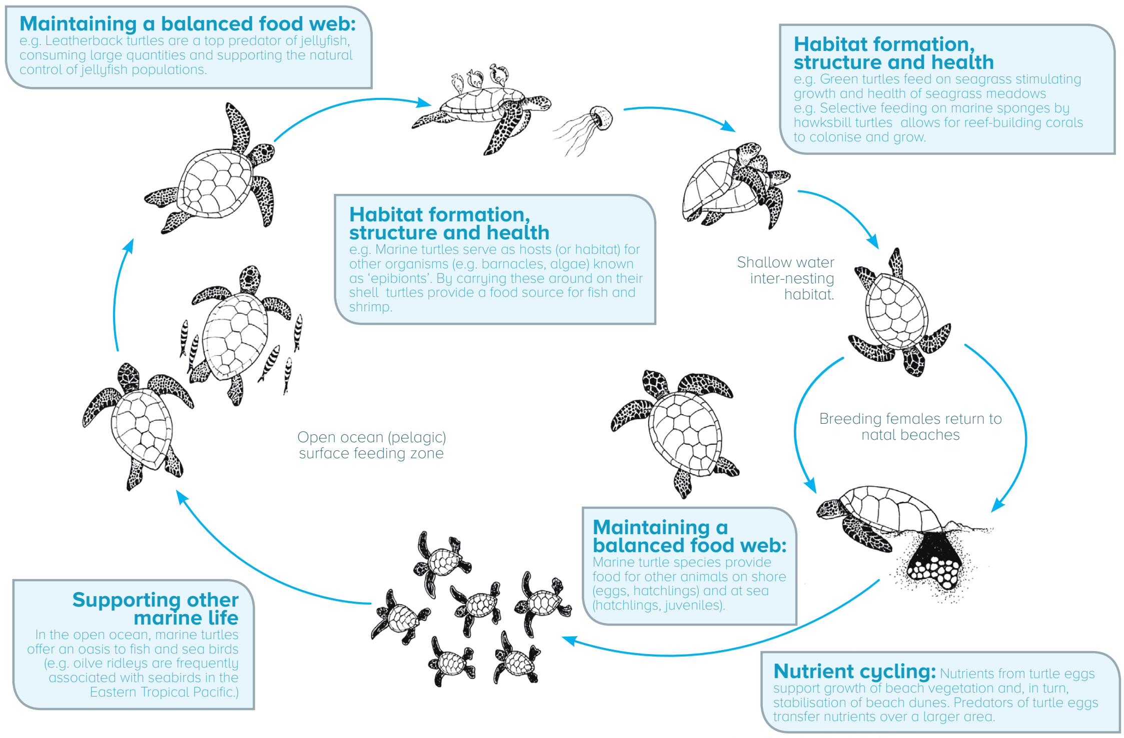
Marine ecosystems rely upon a network of interactions among individuals and groups of organisms. These interactions can influence ecosystem structure and function across multiple scales, from the behaviour of individual species to the dynamics of entire systems. Not all species are equal in contributing to the structure and function of marine communities. Abundant species are like columns; they are important because they give support to a community, and they are easy to detect because their presence is very evident[67]. Rarer species may be important despite their relatively low abundance, because they sustain the community by keeping its diversity high, providing or modifying habitat and altering nutrient dynamics. These keystone species are small elements that sustain complex ecological systems[67]. Top predators, ecosystem engineers, and species that link marine and terrestrial systems are often considered keystone species and essential to marine ecosystem function[7]. Many such species are rare and threatened.

Whilst we know relatively little about the exact ecological roles of most marine species, the impacts of their loss would likely be varied and context-dependent. Data on life history traits, habitat requirements and interactions with other species and with the environment are also often lacking[7]. What we do know is that small changes in marine ecosystems and adverse impacts on keystone and other highly interactive species can lead to disproportionate, perhaps irreversible, changes at a system level. In some cases, leading to the collapse of the entire system[68].

Credit: Michangelo Pignani/FFI

Figure 6: Conceptual diagram illustrating the complex life cycle of marine turtles and their interaction with ecosystems in the water and on land (top; adapted from [64]; see also the State of the World's Sea Turtles' (SWOT) interactive turtle life cycle diagram for further information[65]); and some of the many different ways in which marine turtles contribute to the health and functioning of marine and coastal ecosystems[66] (bottom).

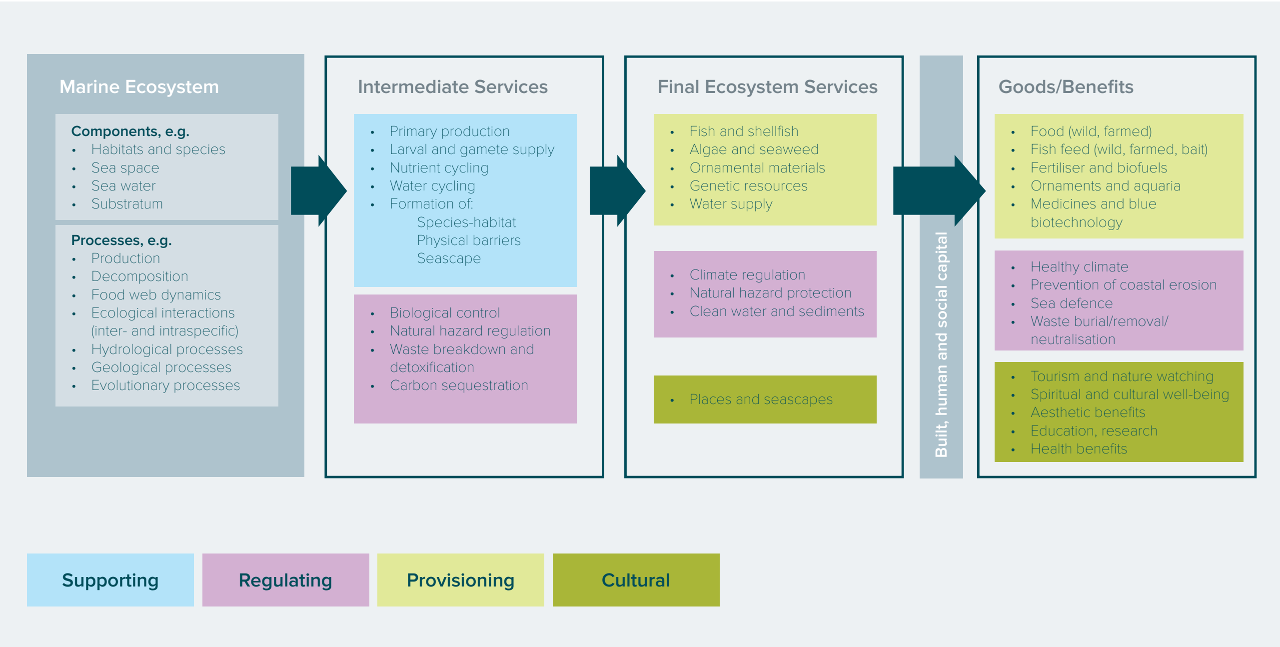




3.4. Marine ecosystem services

Marine ecosystems provide a wide range of services including the provision of food in the form of fisheries, shell fish and seaweed, natural shoreline protection against storms and floods, water quality maintenance, support of tourism and the maintenance of the basic global life support systems (see Figure 7 and Box 11). The seas and coasts around the world are also of great spiritual importance to many people, providing a broad spectrum of cultural and spiritual services. The effects of marine and coastal degradation and a loss of these services are felt inland and often a long way from the coast[69].

Figure 7: The classification of ecosystem services and goods and benefits for coastal and marine ecosystems. (Reproduced with kind permission of the UKNEA[70])



Some marine ecosystems provide supporting (or intermediate) services. For example, estuaries, mangroves, lagoons, seagrasses, and kelp forests serve as nurseries for both inshore and offshore fish, many of which are commercially significant. Ecosystems such as mangroves, seagrasses and mudflats also provide key regulating services through shoreline stabilisation, protection from floods and soil erosion and the processing of pollutants. The services provided by different habitats result from interactions among plants, animals, and microbes and their physical environment.

To understand the relative importance of ecosystem services, we need a fuller understanding of where they are provided, who benefits from them, and how different activities impact on an ecosystem's ability to provide services. For this to be possible, we need to understand the ecosystems themselves: how they work, what affects them, and how their biodiversity contributes to service provision (see Box 4 and Figure 7).

3.5. The complex relationship between biodiversity and ecosystem services

The relationship between biodiversity and ecosystem services is complex and defining the linkage between the two has proved challenging[75]. This is because our knowledge of marine biodiversity is limited and while we know certain ecosystem services are produced by certain habitats, we rarely understand which groups of species and processes are responsible for maintaining a given service.

In the marine environment, biodiversity provides direct ecosystem services such as fish stocks or seaweeds for harvest. Biodiversity can also supply regulatory ecosystem services, for example by providing the species assemblages that filter waste from the environment, or the mangroves or reef systems that protect coastlines from storms. Moreover, the functioning of an ecosystem and the ecosystem services it supports often promote the necessary conditions needed for biodiversity to thrive in an environment. For example, nutrient uptake and sediment transport in the water column (underpinning ecosystem function)

Box 11: The importance of coastal and marine ecosystems for people

- Fifty percent of global primary production[i] occurs in the oceans.
- Nearly 35 million jobs globally are directly linked to ocean fisheries, as well as the livelihoods of at least 300 million people[53].
- The coastal boundary zone that surrounds the continents is the most productive part of the world ocean, yielding about 90% of marine fisheries catches. Overall, coastal and marine fisheries landings averaged 82.4 million tons per year during 1991–2000 (with a declining trend now largely attributed to overfishing)[71].
- Conservative estimates of the value of ecosystem services provided by seagrass beds globally were estimated to be in the order of US$19,000 per hectare per year in 1997 [72].
- Limited research has been undertaken in deep sea environments. However, some deep sea habitats, such as seamounts, are known to be important to commercial fishing. Researchers in the Pacific have observed deep sea species in the stomach contents of commercially important fish[53].
- The buffering capacity of the deep sea plays a crucial role in mitigating the climatic changes caused by anthropogenic emissions: the biological carbon pump is very important in the global carbon cycle, transferring approximately 5-15 billion tons of carbon each year from the surface ocean to the oceans interior[58]. This is around the same amount as the annual increase in carbon dioxide in the atmosphere driven by human fossil fuel use. Some marine habitats, such as kelp and seagrass beds, sequester more carbon per unit area than many productive terrestrial habitats[73]. Further, the deep sea environment plays a key role in the cycling of other nutrients such as nitrogen, silica, phosphorus, hydrogen, and sulphur[58].


Credit: Pippa Howard/FFI

- Communities all around the world have a connection with the marine environment for both recreational use and spiritual and cultural practices. In some seascapes the cultural component has evolved to sustain the biodiversity and ecosystem integrity on which it is dependent[74].

i Primary production is the conversion of energy into organic matter through photosynthesis and chemosynthesis

supports the regulating ecosystem service of water quality and associated biodiversity (e.g. plankton). Impacting one component of an ecosystem, be it a species or a process, can therefore have far reaching consequences because of these complex interactions.

Meta-analysis studies have revealed trends in the positive relationship between biodiversity and ecosystem services[76]. Evidence suggests that greater biological diversity increases the ecological stability of marine and coastal ecosystems whilst also promoting resilience and buffering against damaging impacts. A higher diversity of species in an ecosystem is required to support a wider spectrum of ecosystem functions, directly linked to the breadth and integrity of ecosystem services. For example, a study on seagrass communities found a strong positive relationship between the diversity of seagrass species, the number of ecosystem functions they support and the resultant ecosystem services produced[48].

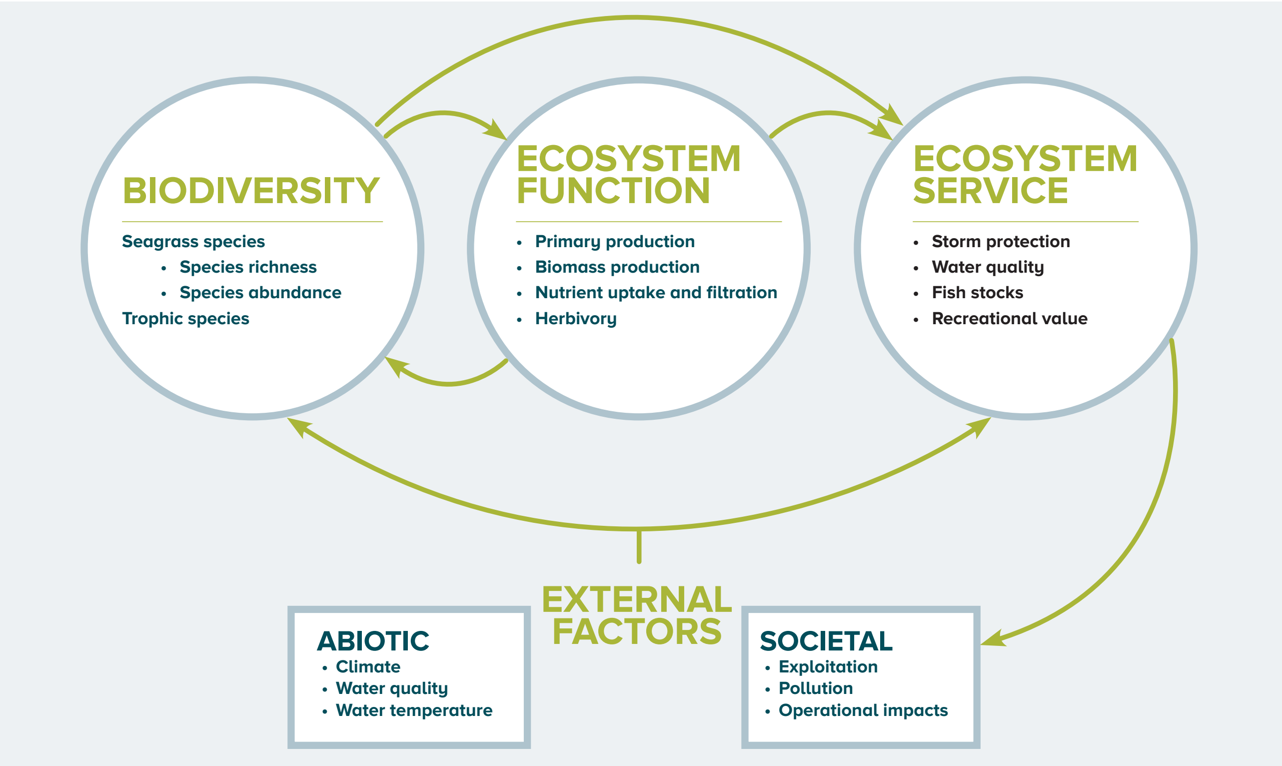
The complementary nature of species relationships is often influential in supporting ecosystem functions and resultant ecosystem services. A prominent aquatic example is the function of algae assemblages in their ability to filter water of pollution, where a higher diversity of species occupy a higher range of niches and therefore collectively have a higher uptake of harmful nutrients in the ecosystem[77].

Conversely, the loss of species in both coastal and marine environments has been shown to negatively impact the stability and potential recovery of an ecosystem and can be directly associated with a reduction in ecosystem services of fish stocks, nursery habitat and water filtration[78]. Loss of biodiversity reduces the ability and efficiency through which ecological communities process nutrients, produce biomass and decompose and recycle nutrients in marine systems. In pelagic ecosystems, impacts to plankton dominant primary producers has a significant effect on the food web structure and this ultimately affects ecosystem services such as fish stocks, decomposition and carbon fixing[79]. In a similar way, overfishing of top or predators in marine systems can impact ecosystem services, such as the loss of large reef fish resulting in the degradation or loss of coral reefs and the associated protection against storm surges and nurseries for commercial fish species[80].

However, high biodiversity in ecosystems does not necessarily correlate with higher yield or diversity of ecosystem services. Despite diverse communities being considered more productive and supporting a wider range of ecosystem services, it is often single or key species which have a significant influence on these ecosystem services[81].

Understanding species and their ecological role in the environment is therefore important for linking biodiversity and ecosystem services and for employing effective management and mitigation measures that are based on an understanding of ecosystem components and respond to the need to maintain ecological integrity and function thereby taking an ecosystem approach (see Figure 8).

Figure 8: Illustration of the complex relationships between biodiversity, ecosystem function and ecosystem services associated with seagrass habitat.



4 Impacts and preventative mitigation measures

This section provides guidance on assessing impacts to BES, whether as part of a full ESIA process or as part of an internal risk assessment exercise. It is designed to support industry led environmental impact and management processes such as **OGP's E-SHRIMP**.

The process of impact assessment is fundamental to understanding how, when and to what degree a project may impact BES, which in turn is essential for developing effective mitigations. Below the process of impact assessment is outlined, referring to a range of recent guidance.

Following this, impacts and preventative mitigations relating to BES are presented for each phase of the oil and gas project cycle.

Credit: Nicky Jenner

4.1. The impact assessment process

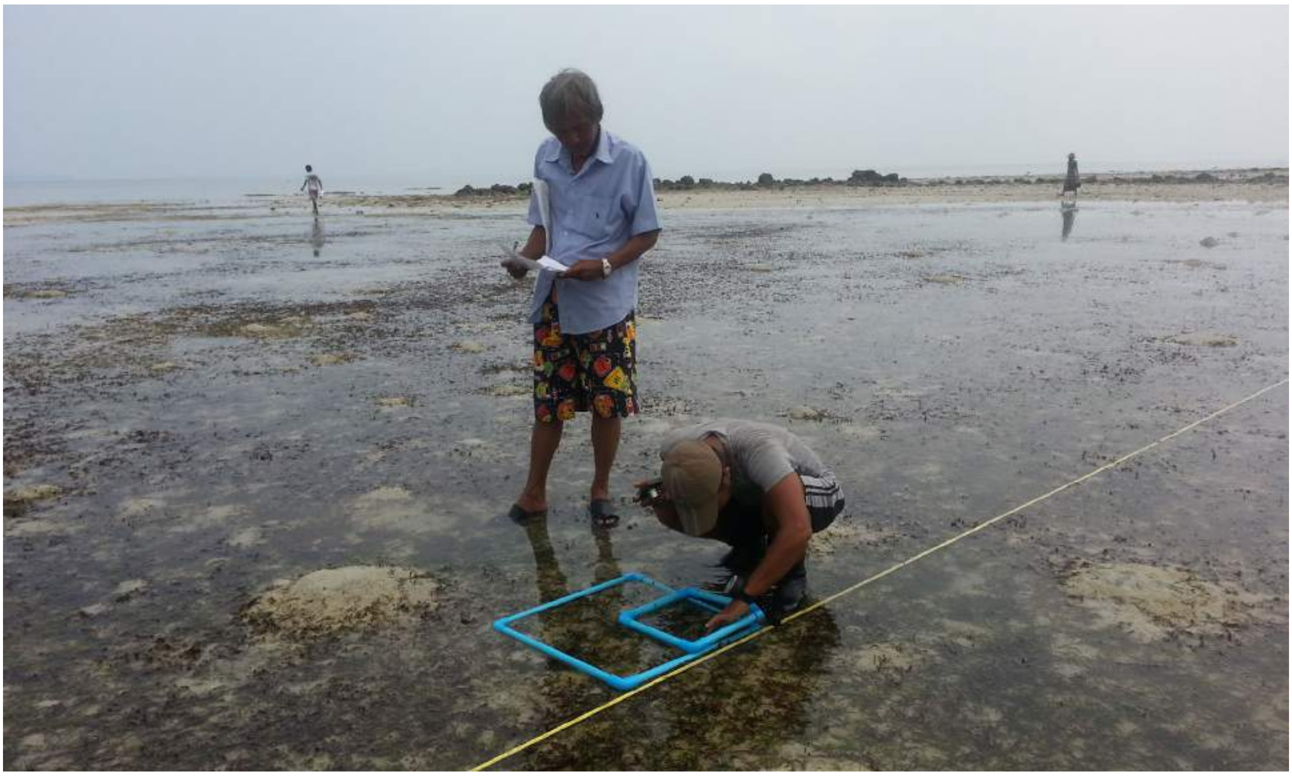
Impact assessment, simply defined, is the process of identifying the future consequences of a current or proposed action. In the context of an oil and gas operation, an impact assessment is commonly undertaken as part of the ESIA process, but may also form part of a stand-alone risk assessment during operations. In either case, an impact assessment can only ever be as good as the data it is based upon, and for this reason a robust baseline of BES information is required. For further information on collecting baseline data please refer to Gullison et al. (2015) and Appendix 4.

In this section we provide a brief summary of the impact assessment process and refer readers to existing documents where further details are required. Effective impact assessments and management plans rely upon:

1. Information on biodiversity (e.g., taxonomic descriptions of species, conservation status assessments of species, conservation status assessments of ecosystems, distribution maps of species and habitats at a scale that is appropriate for project planning, species' ecological requirements and roles, and understanding of sensitivity to stressors);
2. Information on ecological processes that maintain the viability of biodiversity and ecosystem services, including predator-prey trophic interactions, competition, dispersal of juveniles and migrations and aggregation or breeding grounds;
3. Information on ecosystem services, including both supply and demand aspects (see Appendix 4 for guidance);
4. Identification of direct, indirect, and cumulative impacts (i.e., placing the project in the context of resource use trends to ascertain how it contributes to impacts at seascape scale and/or across the sea/land interface); and
5. Identification of priorities for biodiversity conservation (e.g., existing and planned protected areas, National Biodiversity Strategies and Action Plans), sustainable development strategies, poverty alleviation targets and climate adaptation plans).

Analysis of alternatives

As part of the impact assessment process, it is important to include a comparison or analysis of project alternatives. These alternatives are judged against a set of criteria including environmental, social, financial, technological and health and safety among others. In this way, an objective decision can be made about the most appropriate project alternative to proceed with. If the impact assessment is part of a formal ESIA then it is necessary at a minimum, to include an analysis of a "no project" scenario. Additional comparisons may include different project locations, engineering options and designs.



Credit: FFI

Impact identification

The next step is to determine those impacts from project activities which will potentially impact high value biodiversity as identified in the baseline studies. There are three types of impact to consider:

Direct impacts the physical footprint of project activities (including project infrastructure and the incremental transportation and energy infrastructure required to support it) plus the area affected by emissions and effluents;

Indirect impacts the physical footprint of non-project activities in the surrounding area that are caused or stimulated by the project plus the area affected by their emissions and effluents; and

Cumulative impacts the overall impacts occurring in the project seascape caused by the project and non-project activities (related and unrelated to the project), generally including clusters of projects, land use change trends, and/or foreseeable developments.

It is considered good practice to assess all three types of impact. It should be recognised that indirect impacts, especially those relating to the influx of people to a project area in anticipation of its development, may be considerable and even outweigh direct project impacts.

In identifying impacts to BES, all project activities should be considered for each stages of a project's cycle. The potential impacts pre-mitigation should then be determined. The process of impact identification should start as early as possible in the project planning phase, and then be revisited as plans are refined.

Impacts to biodiversity may include direct mortality of species, reduction in reproductive success, disturbance to migrating or feeding patterns, or the destruction or degradation of habitats. It should be noted that the loss of a small number of individuals that play a keystone role in ecosystem will have disproportionate effect upon the entire system, so the identification of such keystone species is vital (even small changes in ecosystems and disruptions to keystone species can be magnified, leading to system shifts and even failure).

Impacts to ecosystem services may include degradation of nurseries for important fish species, loss of access to areas for shellfish collection, visual impact to areas of tourism or cultural value, or the loss of habitats important for storm protection, such as sand dunes.

Impact characterisation

The potential project impacts must be characterised in terms of their actual changes to biodiversity (e.g. the number of individuals affected or the area of habitat degraded). This stage is described further in Hardner et al. (2015)[84]. Changes in habitat condition can be measured through a proxy such as 'intactness' and such a measure can be a valid proxy for ecological processes, ecosystem health or the provision of ecosystem services, where such links have been identified (see Section 3.5 for a more detailed discussion of the linkages between biodiversity and ecosystem services).

Assessment of consequence and risk

Consequence is assessed in terms of how impacts alter the viability of a biodiversity value (in other words, the ability of a biodiversity value to persist over time). The viability of a biodiversity value is a function of its irreplaceability[i] and vulnerability[ii]. There are various means of scaling consequence, including using the IUCN Redlist approach, as covered in Hardner et al. (2015).

Further, consideration must be given to the ecological roles of species, the collective effects of losing species and how this may affect ecosystem function, especially in the case of keystone species, bearing in mind that small changes in marine ecosystem can percolate up to have system level impacts.

The assessment of risk involves the combining of consequence and the likelihood of such an impact occurring in a standard risk assessment matrix, leading to an output score of low, medium, high, or critical risk. This final score then determines what action should be taken, depending upon legislation, lender standards or company policy.

i Irreplaceability relates to the number of sites or the geographic extent where the value is present; if a biodiversity value (for example, a rare habitat type) occurs only at a few sites, then it is highly irreplaceable.

ii Vulnerability relates to the impact and likelihood of existing and future threats; a vulnerable biodiversity value is one that has experienced rapid loss over recent history and/or is faced by current threats that will lead to rapid loss.

Stakeholder engagement

The impact assessment process requires the input of marine biodiversity specialists who can use their knowledge to help determine the likely impacts to marine biodiversity, characterise the extent, duration and severity of such impacts, and to develop appropriate mitigation measures.

For ecosystem services, there must be detailed consultations with a wide range of stakeholders to identify, characterise and prioritise ecosystem services and to determine the predicted impacts of project activities upon these services (see Principle 7 in Section 2, and Appendix 4).

Credit: Robert Howard/FFI

This GPG recognises that sometimes relevant data may be difficult to obtain. The extent to which such gaps need to be addressed must be determined in consultation with stakeholders including subject experts, government authorities, affected communities and, where applicable, lenders. Fundamentally, a transparent and consultative process is recommended to ensure that what is known and not known is fully communicated and that uncertainty is addressed through a precautionary approach.

4.2. Impact and mitigation tables

Oil and gas companies operating in marine environments can have impacts on BES at all stages of the project lifecycle. While some impacts can be restricted to particular project phases, others can occur at all phases throughout the project lifespan, from seismic surveys through to decommissioning. By understanding how their activities impact BES, companies can apply specific measures to help to mitigate and reduce these impacts.

This section assesses the impacts oil and gas projects may have on marine BES during different phases of a project and the mitigation options that exist to reduce these impacts. Project phases are categorised as follows: seismic surveys, exploration drilling, field development, production and operations, and decommissioning.

A table has been developed for each phase of the project cycle and for supporting services such as shipping and ports. In each table a range of impacts has been identified in relation to the main oil and gas activities associated with that project phase. So, for exploration drilling, impacts associated with the presence of a temporary drill rig are identified, including anchoring, ballast water management and lighting as well as impacts relating to the actual drilling.

For each activity, the predicted impacts to both biodiversity and ecosystem services are considered, each in separate columns in recognition of the complex and non-linear relationship between them.

Mitigation measures are identified for each impact. The tables intentionally focus upon preventative measures designed to reduce impacts through avoidance and minimisation. This is because there is much uncertainty around our knowledge on marine BES and our ability to predict impacts, so a precautionary approach is paramount. The so-called remedial measures of restoration and offsetting are dealt with separately in Sections 5 and 6.

Mitigations are usually tried and tested methods with documented operational success. However, the field is fast evolving with new approaches rapidly being developed. To reflect this, a number of emerging and more aspirational approaches are also included here. Case studies and references are provided wherever available.

It is important to note the tables are not designed to be comprehensive in their identification of impacts or mitigations, but rather provide a repository of current approaches to the management of impacts to marine BES, set in the framework of the mitigation hierarchy. Further, it is essential to note that the characterisation of impacts (and the subsequent application of mitigations) to marine BES will be highly context-specific such that an impact that may have minor effects upon an element of BES in one location may have a more severe effect in another location. Therefore, it is essential to understand as much as possible about the local context before embarking on the assessment of impacts.

4.3. Shipping

Shipping is the movement of materials and equipment using marine vessels. It is considered here as a separate activity because shipping occurs at all phases of the project cycle. There are many kinds of shipping that support the oil and gas industry; here we consider upstream shipping including survey vessels, construction vessels, drilling platforms, support vessels, vessels carrying dry cargo and bulk carriers of crude oil and natural gas. This includes a large range of vessel designs, sizes and operations.

Impacts from shipping include pollutants such as paints, spills, and wastes, noise including operational noise and seismic surveys, lighting and disturbance from the vessel's movement through the water. These are considered in detail in Table 1.

Credit: Woodside Energy Ltd

Table 1: Impacts associated with shipping/maritime traffic on marine biodiversity and ecosystem services, and recommended mitigation activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Sea vessel presence and movement Sea vessels used at all stages of an oil and gas operation.	Sea vessels moving to/from the worksite to shore could collide with marine species and block feeding areas and migration pathways[88]. Restricted areas for shipping prevent access to unauthorised vessels. Minor releases of pollutants/wastes from ships. Non-physical disturbance such as noise & visual presence.	• Injury and potential mortality of marine species including cetaceans, pinnipeds, sirenia, seals, turtles and sea birds through collision with vessel. • Disturbance to migration, feeding and breeding patterns through noise and light from vessel, e.g. where vessel is adjacent to intertidal areas used by migratory birds[87].	• Impacts to cultural services (e.g. ecotourism, whale watching, reef diving) related to the frequency or timing of shipping. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to movement of vessels with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Restricted access to traditional fishing grounds by local communities, reducing ability of subsistence fishers to catch fish and potentially increasing competition between fishers in surrounding waters.	Avoid	Monitor for presence and movements of large cetaceans, sirenia, and turtles (using observers on ships - Marine Mammal Observers (MMO) - and/or acoustic monitoring devices) so that collisions with vessels can be avoided. This mitigation action will only be effective for vessels capable of rapid manoeuvres (e.g. vessels of a few thousand GT or less)[88,89,90]. i
				Avoid	During planning phase, plan for all ships to stay away from the coast and sensitive areas, e.g. Marine Protected Areas (MPAS), areas of shallow and deep water corals, areas of artisanal fisheries and the areas devoted to marine aquaculture, registered with the National Authority for fisheries and marine resources.
				Avoid / minimise	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.
				Minimise	Limit vessel speed in sensitive areas. Risk of collision with whales increases significantly at speeds of >10 knots[91,92]. ii
				Minimise	Design vessel routes to avoid areas of known high concentration of marine mammals and reptiles[94].
Anchoring Anchoring vessels offshore.	Physical damage by anchor and anchor chains to benthic habitat and species. Non-physical disturbance such as noise and visual.	• Anchoring vessels may disturb or damage sensitive benthic communities, including mortality to sessile or slow-moving benthic organisms.	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impacts of noise and vibration. • Visual / aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Avoid	Restrict users to designated anchorage areas that avoid designated protected areas and sensitive marine habitats such as coral reef[87]. Dynamic positioning (using thrusters) could also minimise the use of anchors.
				Minimise	Implement designated anchorages that limit interaction between anchored vessels and traditional and/or commercial fishing activities[95].
Ship and boat wash Ship and boat wash as a result of the movement of vessels.	Changes in physical regime such as an increase in waves and sediment transport.	• Wash from vessels may cause changes to the hydrodynamic regime which result in erosion of intertidal and shallow subtidal habitats and disturbance to shallow water communities.	• Increased turbidity from sedimentation impacts on the physico-chemical conditions of the water column reducing productivity of fisheries.	Minimise	Implement site specific measures to minimise ships' wash in the proximity of vulnerable shores. For example zoned areas to reduce speeds[95].
				Minimise	Investigate the feasibility of protecting intertidal features from ship wash by creating breakwaters where there is evidence that ships wash is causing the erosion of designated intertidal flats, where all other appropriate measures have been undertaken or as a precautionary approach[95].

i Monitoring is critical in areas of concentrations of sirenia (dugongs, manatees) and marine turtles. A good example of MMOs being used for mitigation comes from the Sakhalin Energy project, where MMOs are routinely used in operations to minimise the risk of collision[93]
ii A good example of this comes from Sakhalin Energy, which limits the number of vessels engaged into the offshore operations and uses ships with low-noise equipment and engines onboard, sets a limited maximum speed for the vessels as well as narrows their routes via specially assigned corridors[11].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Antifouling paints Used to coat bottoms of sea vessels to prevent sea life such as algae and molluscs attaching themselves to the hull, thereby slowing down the ship and increasing fuel consumption.	Antifouling paints, which can contain potent biocides (e.g. Tributyltin - TBT), are released into wider marine community.	• Deformities in oysters. • Malformations in shellfish. • Sex changes in whelks. • Death of larvae (e.g. death of brine shrimp larvae by copper based paints).	• Impacts to collection fisheries reliant upon shellfish and crustaceans. • Impacts to human health and nutrition due to health of fish caught and consumed. • Bioaccumulation leading to impacts to health of higher predators and scavengers.	Avoid	Do not use antifouling paints that contain harmful organotins; ships should not apply or re-apply organotin compounds which act as biocides in anti-fouling systems. This applies to all ships, including fixed and floating platforms[96]. iii
				Minimise	For ships that have already had antifouling paints that contain harmful organotins applied to their hulls or external parts of surfaces, a coating that forms a barrier to such compounds leaching from the anti-fouling systems into the marine environment should be applied[96].
Ballast water Water used as ballast to stabilise vessels at sea when cargo tanks are empty.	Discharge of ballast water in different location to where it was pumped in to vessel can result in the introduction of alien (non-native) species into the marine environment. Alien species can include microorganisms, small invertebrates, eggs, cysts and larvae of various species, which can become established in their new environment to become alien invasive species (AIS) under certain conditions.	• Decline or extinction of native species through AIS competing with native species for space and food. • Decline or extinction of native species through AIS preying upon native species. • Decline or extinction of native species through introduction of diseases and pathogens. • Alteration of food web dynamics through reduction or removal of key populations. • Alteration of habitat. • Alteration of environmental condition, e.g. decreased water clarity. iv	• Impacts for provisioning services if introduced diseases and AIS negatively affect fish and other species important to commercial or subsistence fisheries.	Avoid	Ensure the ports used have facilities to receive and treat ballast water in an environmentally safe way to eliminate all organisms and pathogens.

iii Requirement under International Maritime Organisation's (IMO's) International Convention on the Control of Harmful Antifouling Systems on Ships (entered into force in 2008)
iv The spread of AIS is recognised as one of the greatest threats to the ecological and economic well-being of the planet. Direct and indirect health effects are becoming increasingly serious and the damage to the environment is often irreversible[97]. Impacts from AIS offshore can be transferred to coastal areas in currents and tides

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
				Minimise	As per the Ballast Water Management Convention ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. The Ballast Water Management Plan is specific to each ship and includes a detailed description of the actions to be taken to implement the management requirements and practices[97,98,99]. All ships must also carry a ballast water record book to record when ballast water is taken on board; circulated or treated for Ballast Water Management purposes; and discharged to sea. It should also record when ballast water is discharged to a reception facility and accidental or other exceptional discharges of ballast water. Ships must also carry an international ballast water management certificate[97].
				Minimise	Wherever possible ballast water should be taken on-board outside of port waters and as far away from the coast as possible[97,98,99]. The uptake of ballast water should be minimised or, where practicable, avoided in areas and situations such as: • In darkness when organisms may rise up in the water column • In very shallow water • Where propellers may stir up sediment • Areas with current large phytoplankton blooms • Nearby sewage outfalls • Where a tidal stream is known to be more turbid • Where tidal flushing is known to be poor • In areas close to aquaculture • Where dredging is being or has recently been carried out
				Minimise	Tanks used for holding other purposes (e.g. grey water, treated sewage) should be cleaned prior to use for holding ballast water.
				Minimise	Ensure treatment of ballast water through either solid-liquid separation (the separation of suspended solid material, including the larger suspended micro-organisms, from ballast water either by sedimentation or by surface filtration) or by disinfection (removes and/or inactivates microorganisms through chemical inactivation, physiochemical inactivation or asphyxiation)[100]. Solid-liquid separation processes produce a waste stream which required appropriate management and during ballasting they can be safely discharged at the point where they were taken up.
				Minimise	Under regulation B-4 of the Ballast Water Management Convention, all ships using ballast water exchange should, whenever possible, conduct ballast water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth, taking in to account Guidelines developed by IMO. In cases where this is not possible, ballast water exchange should be conducted as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth[97]. When these requirements cannot be met, ships should conduct ballast water exchange in designated areas, or conduct tank-to-tank transfer of ballast water to prevent discharge of high-risk ballast water to the marine environment.
				Minimise	All ships should remove and dispose of sediments from spaces designed to carry ballast water in accordance with the provisions of the ships' ballast water management plan[97].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
<u>Biofoulants on sea vessels</u> Various species attach themselves to the hulls of sea vessels.	Transportation of biofoulants, such as barnacles, that attach themselves to external surfaces of sea vessels into non-native environments. Biofoulants can become AIS if they become established in their new environment.	• Decline or extinction of native species through AIS competing with native species for space and food. • Decline or extinction of native species through AIS preying upon them. • Decline or extinction of native species through introduction of diseases and pathogens. • Alteration of food web dynamics through reduction or removal of key populations • Alteration of habitat. • Alteration of environmental condition, e.g. decreased water clarity.	• Impacts for provisioning services if AIS negatively affect fish and other species important to commercial or subsistence fisheries.	Minimise	Ensure vessel(s) have a documented Biofoul Management Plan[99,101,102].
				Minimise	Investigate all technologies to reduce biofouling - follow, for example, best practice in prevention and management of AIS in the oil and gas Industry (IPIECA 2010)[99].
				Minimise	Apply hot water treatments to reduce biofouling (including "thermal shock" and Hull Surface Treatment)[103].
				Minimise	Develop biofoul risk assessment and quarantine management system for all operational vessels, including supply tankers.
				Minimise	Ensure anti-fouling treatments and records are up-to-date.
<u>Noise</u> Noise generated by sea vessels can include continuous, low frequency noises, and noises generated from machinery such as propellers.	Noise generated in marine environment.	• Impacts of noise on marine mammals may be behavioural or physiological; behavioural changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant relationships, masking of biologically important sounds and avoidance of the noise sources[104]. • Physiological effects of underwater noise may include a reduction in animal hearing sensitivity or secondary effects associated with other systems inclding the vestibular system, reproductive system, nervous system and liver[104]. • Noise emissions that interfere with natural sounds in the marine environment may affect the timing of social and reproductive behaviour[105], particularly if the disturbance to vulnerable or endangered animals coincides with very short breeding or spawning periods. This could result in reduced breeding success and possible mortality. • Impacts to communication in marine mammals and other marine organisms[106].	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impacts of noise and vibration. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Minimise	Ensure gradual start-up of engines and thrusters where possible, to provide opportunity for species to take evasive action[107].
				Minimise	Propeller and thruster noise: Many options for reducing noise from propellers and thrusters currently exist and have been implemented on a large number of commercial vessels. Good propeller design, including large diameter, slow turning props (reduced cavitation), as well as blade shapes optimised to flow conditions, increased skew, and hull modifications to improve flow conditions are effective ways to reduce underwater noise. Cold ironing, or shore connection, or alternative maritime power (AMP), when ships are at berth[108,109].
				Minimise	Use hydrophones to monitor ship noises. Implement noise reduction measures (non-essential equipment shut down) when cumulative noise load exceeds 120dB@ 250m from vessel[110].
<u>Lighting</u> Artificial lighting generated from sea vessels.	Light emitted from sea vessels cause light pollution in the marine environment.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight and condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • Fish may be attracted to ship's light source with larger aggregations increasing predation rates around sea vessels, resulting in loss of species abundance.	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to light disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Minimise	Minimise artificial lighting to that required for navigation and operational safety requirements[112]. For example, install security lights on motion- sensitive switches.
				Minimise	Use directional lighting only to illuminate rigs and vessels as necessary. Where optional, point away from the shore.
				Minimise	Use light shielding to focus light towards work areas and reduce light 'spill' into sensitive habitats.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing its attraction for migratory birds and turtles[113]. For turtles - use light sources that are 'turtles friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium- vapour lighting is the purest yellow light source and recommended due to being the best commercially available solution[114].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Hazardous wastes Planned or accidental release of toxic and non-toxic substances during field development.	Discharge of hazardous materials (hazmats) to marine environment. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidising substances; toxic materials; radioactive material; and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from exposure to hazardous materials. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column from contamination by oil, solvents and additives. • Impacts to human health and nutrition due to bio-accumulation of chemicals, affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) and associated revenues gained by tour operators through direct mortality from chemical incidents.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only. v
				Avoid / minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines should be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning port infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Install permanent 'scrub-off' facilities to collect maintenance residues from operational areas.
				Minimise	Develop a surface water management plan to limit risk of chemicals entering the marine environment, e.g. contain and collect surface water from maintenance areas and test and treat before releasing to the marine environment.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their Material Safety Data Sheets (MSDS). Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.
Inorganic waste Non-hazardous inorganic waste (e.g. plastic) generated on sea vessels.	Pullution of marine environment by release of inorganic waste, e.g. plastic, lumber, metal, concrete, etc.	• Ingestion of plastic waste can cause individuals to die of starvation or malnutrition. • Diving birds can become entangled in plastic waste - can lead to infection, loss of limbs or death. • Plastic waste can leach toxic substances to sediments and water where it can be absorbed by small algae and animals and cause bioaccumulation in other animals feeding on them[115]. • Toxic plastics can be ingested directly by fish, exposing species further up the food chain to these pollutants - can lead to death from toxic poisoning[116]. • Habitat degradation (seagrass and coral reef) due to smothering and reduced light access.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality and disruption of food web caused by plastics. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impact to aesthetic beauty from plastic waste and direct mortality to species important to tourism. • Impacts to human health and nutrition due to health of fish caught and consumed.	Avoid	Do not dispose of plastic waste overboard; collect all plastic waste for onshore disposal by reputable waste management contractors only, and seek recycling options where available[117]. vi
				Minimise	Efforts should be made to eliminate, reduce, or recycle wastes at all times[118].
				Minimise	A management plan must be developed and implemented to minimise discharge of each type of solid waste. At a minimum, IFC EHS General Guidelines must be followed. The plan should consider upland disposal of solid wastes in approved sites.
				Minimise	Staff will be given induction to manage solid waste for recycling and disposal.

v Overboard disposal of all types of chemical waste from vessels is prohibited under MARPOL[1] Annex II and III
vi Overboard disposal of all types of solid waste from vessels is prohibited under MARPOL Annex V

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Organic waste Non-hazardous organic waste (e.g. food waste) generated on sea vessels.	Sea vessels moving to/from the worksite to shore dispose of wastes (including kitchen waste, effluent, sewage and grey water) at sea.	• In near-coastal waters or estuaries with poor flushing, can result in reduced benthos biodiversity and abundance, changes in fish behaviour, stress and acute or latent mortality of marine species through lack of oxygen. • May introduce pathogens and cause turbidity that would affect local sensitive organisms with limited mobility (benthos and eggs). • Increase in biological oxygen demand and a reduction in habitat quality[119]. Can result in eutrophication (algal blooms).	• Impact to regulating service of waste assimilation through inundation of waste; impacts to human health from increased waste in environment. • Impact on provisioning services through impacts to changing behaviour of nektonic (aquatic animals that are able to swim and move independently of water currents) and other species attracted to nutrients from waste. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column from increased nutrient levels and suspended matter.	Avoid	Treat all sewage and grey water according to MARPOL requirements prior to discharge OR no disposal at sea - disposal at port by a reputable waste contractor only[120].
				Avoid	Collect and compact all domestic waste for onshore disposal. Ensure detailed documentation and manifesting. Ensure that onshore receiving and disposal companies meet local and international requirements.
				Minimise	Use waste segregation at source for different types (organic, inorganic industrial wastes, etc.).
				Minimise	No disposal of untreated sewage or grey-water within 12 nautical miles of land[120].
				Minimise	Store used cooking oils in suitably contained areas. Limit quantities stored to a minimum. Ensure detailed control documentation and manifesting for disposal.
Sea vessel emissions Gaseous emissions from equipment and engines aboard sea vessels.	Emissions from sea vessels have constituents (NOx, SOx, CO2, VOCs, particulates) that can contribute to water acidification and nitrification, climate change (carbon emissions) and deposition of particulates on land and in water.	• Loss/reduction in quality of habitat. • Behavioural changes by marine species. • Injury or death of marine species as a result of toxicity.	• Impact to regulating services of waste assimilation and productivity through emissions. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column. • Eventual impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality and ecological imbalances caused by emissions.	Minimise	Fit exhaust gas cleaning systems[121].
				Minimise	Implement technical and operational energy efficiency measures to reduce CO_2 emissions.
				Minimise	Burn 'clean' fuel only (<0.1% sulphur content).
				Minimise	Minimise number of supply vessel trips to site - i.e. maximise the efficiency of supply vessel use.

4.4. Port construction and operation

Port facilities are frequently required for processing and/or transportation of oil and gas from offshore and onshore production areas. Port infrastructure is generally located at the interface between terrestrial and marine environments. This section outlines the adverse impacts of ports as well as associated mitigation measures on marine habitats including estuarine and coastal habitats (terrestrial impacts are not considered here).

Credit: Woodside Energy Ltd

Port infrastructure can include:

- LNG loading facility, including access trestles to connect inshore processing plants to offshore loading platforms, loading platforms for loading LNG and mooring berths
- Material Offloading Facilities (MOF) which enable the transportation of construction material, equipment and personnel to a site as well as tug boat mooring
- Liquefaction and export facilities
- Shipping channels and/or port berths
- Sea water intake pipes
- Water outfall pipes.

Key adverse processes that may result from port construction and operation activities include direct physical disturbance of marine habitats, alteration of water quality parameters as a result of capital and maintenance dredging or discharge of process water, direct injury or disturbance to marine fauna from vessel presence, artificial lighting and underwater noise resulting in impacts to behaviour, communication, and navigation of marine fauna, introduced marine species and changes in levels of non-toxic contaminants (suspended sediments, turbidity, and nutrient/organic enrichment) and toxic contaminants. Additionally, there could be restrictions to fishing or transportation areas normally used by local communities.

Credit: Pippa Howard

Table 2: Impacts associated with port infrastructure (construction and operation) on marine biodiversity and ecosystem services, and recommended mitigation activities to avoid and minimise impacts

Source of impact & application in phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping In support of construction and operation of a port.	See 'Shipping' table for potential impacts and mitigations relating to shipping.				
Port infrastructure Construction of port infrastructure - physical disturbance and presence of infrastructure in marine environment (e.g. construction of loading jetty, material offloading facility (MOF) or transmission pipelines).	Loss or modification of sensitive benthic habitat (e.g. seagrass beds, seaweed / kelp forests, coral reefs, etc).	• Damage or disturbance to sensitive benthic communities such as seagrass beds and coral reefs (including dependent faunal species, e.g. marine turtles and mammals). • Removal of benthic macroinvertebrate communities in the vicinity of the infrastructure and spoil ground.	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Loss of access to fish that are important to local fishing communities. • Damage or disturbance to regulating habitats (e.g. seagrass beds, seaweed / kelp forests and coral reefs), impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Damage/ disturbance to seaweed/kelp forests impacting regulating and maintenance services of atmospheric composition and climate regulation (e.g. provision of oxygen, absorption of CO_2). • Impact to cultural services through visual presence, damage or disturbance from infrastructure impacting tourism activities (e.g. diving, boating) and associated revenue gained by tour operators.	Avoid	Investigate project design options that will avoid or minimise impacts on sensitive habitats or species such as the use of Floating LNG (FLNG) structures or limiting coastal armouring.
				Avoid	During site selection, locate port facilities and shipping channels away from sensitive inshore marine receptors[9].
				Avoid	At project design stage, avoid the placement of operational structures, pipelines and associated infrastructure in sensitive marine habitats. Project design should be informed by an analysis of the oceanography of the infrastructure route[122] and stakeholder consultation to identify areas of importance for local communities. Note that the distribution and density of sensitive marine habitats (e.g. seagrasses) can be seasonal and vary substantially, and thus conditions for habitats should be optimal at the time of analysis.
				Minimise	Reduce the physical footprint of the port development. Restrict the area cleared and developed as far as possible for both the onshore and offshore port infrastructure.
				Temporal avoidance/minimise	Determine what species are present in an area before commencing construction activities and assess if there are any seasonal considerations that need to be taken in to account such as important migration, rearing or spawning, and which can be avoided or minimised[14].
				Minimise	Remove or recover all materials or objects disposed of in the marine environment during construction and operation[95].
				Minimise	Locate seawater intakes and out-takes away from sensitive receptors and install mesh screens to limit uptake of marine fauna.
				Minimise	Monitor for turtle entrapment within construction site. Adults or hatchlings may become disorientated or trapped in equipment and trenches. Rescued hatchlings should be allowed to crawl unassisted to the sea to enable individuals to imprint the beach. Hatchlings rescued during the heat of the day should be placed in a shaded container with slightly damp beach sand and at nightfall released at the site of hatching or suitable nearby location[123].
	Loss or adverse modification of access to marine resources.		• Interference with and exclusion of traditional, recreational and commercial fishers, and tourism operators.	Avoid	Avoid directly locating port infrastructure, shipping channels, dredge disposal areas in marine areas that support local fishermen or are key to recruitment of commercial species.
				Avoid / minimise	Develop exclusion zones for port construction and operation to meet operational safety requirements, and in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.

Source of impact & application in phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
<u>Port infrastructure</u> Construction of port infrastructure - physical disturbance and presence of infrastructure in estuarine habitat.	Loss or modification of estuarine habitat in the intertidal zone (e.g. salt marsh or mangrove communities).	• Damage or disturbance to estuarine habitat (e.g. saltmarsh and mangrove communities, including dependent faunal species, e.g. migratory wader birds).	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Damage or disturbance to estuarine habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Impact access to provisioning materials such as fertiliser or algae. • Damage/ disturbance to estuarine habitat impacting regulating and maintenance services of atmospheric composition and climate regulation (e.g. provision of oxygen, absorption of CO_2). • Damage or disturbance to nursery, feeding and breeding grounds of marine mammals and migratory birds important for cultural services such as existence values and leisure activities. • Impact to cultural services through visual presence, damage or disturbance from infrastructure directly impacting recreational activities (e.g. birdwatching, photography) and associated revenue gained by tour operators.	Avoid	Site selection – locate port facilities and shipping channels away from sensitive inshore marine habitats important for BES. NB baseline studies should include an assessment of regulating ES.
				Minimise (or temporal avoidance)	Determine what species are present in an area before commencing construction activities and assess if there are any seasonal considerations that need to be taken in to account such as important migration, rearing or spawning, and which can be avoided[14].
				Minimise	Minimise removal and disturbance of intertidal and wetland areas to that necessary to safely construct and operate the site.
				Minimise	Establish procedures for modification of any works while migratory birds are within the construction area (i.e. within 25 metres of any construction activity).
				Minimise	Ensure port infrastructure creates no permanent barriers to fish and other marine fauna and limits modifications to local flow regimes. Port structures should be designed to maintain connectivity between estuarine and/or marine habitats[124,125].
	Disturbance/mobilisation/ oxidation of acid sulphate soils.	• Decline in water quality causing reduced productivity or mortality to inshore marine species. • Disease of fish species linked to exposure to acid water[126]. • changes to communities of water plants, including invasion by acid-tolerant weeds.	• Impact on provisioning services due to availability and/or health of fish caught and consumed. • Impact on aquaculture industries due to disease, habitat degradation and reduced survival rates.	Avoid	Identify and avoid development in coastal or marine areas that contain acid sulphate soils.
				Minimise	Establish contingency measures for suitable treatment of any confirmed acid sulphate soils (e.g. lime neutralisation).
				Minimise	If acid sulphate soils are exposed, excavate and store in a suitably contained area in order to prevent runoff or leachate from exiting the treatment area.
<u>Lighting</u> Artificial lighting used during port construction and operation.	Artificial lighting, used to illuminate port infrastructure, spills into adjacent sensitive habitats.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight and condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • Fish may be attracted to port's light source with larger aggregations increasing predation rates around sea vessels. • Artificial lighting can result in avoidance of nesting beaches by marine turtles and can impact on the ability of hatchlings to orientate after leaving the nest[127,128]. • Artificial lighting may disrupt and disorient sea birds. For example petrel fledglings are known to be attracted to light sources and are subsequently grounded leaving them vulnerable to other threats[129]. i	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic importance (e.g. commercial fish or culturally iconic mammals) due to light disturbance (with species attracted to the lights and then bio-accumulating the toxins released from the port as well as reducing abundance of fish in surrounding areas) with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Minimise	Keep artificial lights to the minimum required to meet navigation and operational safety requirements[112]. For example, install security lights on motion- sensitive switches.
				Minimise	Filter and/or shield lights in order to decrease light intensity for example use hoods and covers to reduce the amount of light spilling[130].
				Minimise	Direct lighting away from sensitive habitats such as nesting beaches and wetlands adjacent to the port site.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing the attraction by migratory birds and turtles[113]. For turtles - use light sources that are 'turtles friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium- vapour lighting is the purest yellow light source and recommended due to being the best commercially available solution[114].
				Minimise	Make personnel working on site aware of threatened and migratory species that may be grounded as a result of artificial lighting.

i The extent of impact will depend on the extent to which sensitive species become accustomed to noise and illumination at night. For example migratory birds have been known to forage and roost in close proximity to existing port developments.

Source of impact & application phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Construction vessels Physical presence of mobile vessels and equipment during port construction.	Vessels moving to/from the work site have the potential to collide with marine fauna and block feeding areas and migration pathways; restricted areas for shipping prevent access to unauthorised vessels.	• Direct injury or mortality of marine fauna (e.g. migratory whales, turtles or migratory birds) as a result of collision with sea vessel. • Disturbance to migration, feeding and breeding patterns. • Behavioural changes or displacement of marine fauna such as marine turtles, whales and migratory wader birds.	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to the frequency or timing of shipping. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to movement of vessels with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Restricted access to traditional fishing grounds by local communities, reducing ability of subsistence fishers to catch fish and potentially increasing competition between fishers in surrounding waters.	Avoid	Monitor for presence and movements of large cetaceans, sirenia, and marine turtles (using observers on ships - Marine Mammal Observers (MMO) - and/or acoustic monitoring devices) so that collisions with vessels can be avoided. This mitigation action will only be effective for vessels capable of rapid manoeuvres (e.g. vessels of a few thousand GT or less)[88,89,90]. ii
				Avoid	Undertake activities outside of sensitive lifecycle periods for relevant species such as breeding or calving season.
				Avoid/minimise	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Apply species-specific management actions to minimise adverse interactions. Interactions between vessels and marine fauna can be minimised through the implementation of speed limits and exclusion zones for construction vessels[131,132,133]. iii
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.
				Minimise	Install boat speed signs and educational signs explaining the importance of adhering to boat speed limits.
				Minimise	Consider the zoning of operational port activities, in space or time, for environmental protection. Keep activities within suitable areas where the impact on important features will be minimised.
Anchoring Anchoring vessels offshore of port loading facilities.	Physical damage by anchor and anchor chains to benthic habitat and species Non-physical disturbance such as noise & visual presence and minor releases of pollutants/wastes from ships.	• Anchoring vessels may disturb or damage sensitive benthic communities, including mortality to sessile or slow-moving benthic organisms • May cause some disturbance through noise and vessel movements, particularly adjacent to intertidal areas used by migratory birds[87].	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impacts of noise and vibration • Visual / aesthetic impact to seascape • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Avoid	During site selection, locate port facilities and shipping channels away from sensitive inshore marine habitats important for BES.
				Minimise	Restrict users to designated anchorage areas that avoid sensitive marine habitats such as coral reef which reduces the overall area of seabed affected by chronic anchor disturbance[87].
				Minimise	Implement designated anchorages that limit interaction between anchored vessels and traditional and/or commercial fishing activities[95].
				Minimise	Install designated marine protection areas that prohibit anchoring in sensitive areas. Erect appropriate signage[95].
Ship and boat wash Shipand boat wash as a result of the movement of vessels during port construction and/or operation	Changes in physical regime such as an increase in waves and sediment transport	• Wash from port vessels may cause changes to the hydrodynamic regime which result in erosion of intertidal and shallow subtidal habitats and disturbance to communities.	• Increased turbidity from sedimentation impacts on the physico-chemical conditions of the water column reducing productivity of fisheries.	Minimise	Implement site specific measures to minimise ships' wash in the proximity of vulnerable shores. For example zoned areas to reduce speeds[95].
				Minimise	Investigate the feasibility of protecting intertidal features from ship wash by creating breakwaters where there is evidence that ships wash is causing the erosion of designated intertidal flats or saltmarsh habitat, where all other appropriate measures have been undertaken or as a precautionary approach[95].
Construction workforce Influx of construction workers in previously remote marine environment.	Recreational and / or illegal fishing leading to impact on marine resources.	• Temporary increase in workforce leading to increased fishing pressure.	• Increased pressure on recreational fish species and disturbance to inshore marine habitat and fauna. • Increased pressure on fish species that are also important to local fishing communities.	Avoid	Locate staff accommodation facilities away from sensitive marine facilities and transport staff to site[134].
				Minimise	Design and implement a bush meat action plan for aquatic bushmeat which includes all products sourced from wild aquatic megafauna[135]. Measures must be context specific but might include the restriction of domestic pets that may prey on native species such as migratory birds or turtles, the employment of beach patrols/eco guards and raising awareness that the harvest of certain marine species is illegal.
				Minimise	Prohibit fishing and hunting on port lease holding, infrastructure and all operational vessels. Prohibit employees and contractors from harvesting or purchasing protected species, e.g. marine turtle products. This should be communicated in a site induction and included in the disciplinary policy.
				Minimise	Restrict access to sensitive marine areas for all employees and the general public[134].
				Minimise	Apply restrictions and enforced speed limits for recreational vessels especially in shallow water.
				Minimise	Raise awareness of all construction staff and contractors of environmental sensitivity and legal protection of local environment.

ii Monitoring is critical in areas of concentrations of sirenia (dugongs, manatees) and marine turtles.
iii The enforcement of boat speed limits especially in shallow water depths will reduce the risk of fatalities and injury to marine fauna such as dugongs and turtles due to boat collisions. For example a speed limit of 4 knots per hour was placed on vessels in the Port of Mackay, Australia. Speeds were restricted to 6 knots in water depths of 2.5 m of less in other ports in Northern Australia.

Source of impact & application in phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Dredging Removal of sediment for the construction or maintenance of shipping channels and port berths.	Removal of benthic habitat; increased turbidity and local sedimentation. Loss or adverse modification of access to marine resources.	• Destruction of sensitive marine habitats, e.g. seagrass. • Destruction of habitat for benthic and burrowing species. • Reduced productivity or mortality due to light limitation. • High rates of sedimentation resulting in burial of sessile flora and fauna. • High levels of suspended sediment interfering with locating prey, and altering the movement patterns of larval fish. • Increase in coral diseases[136] through stress from elevated turbidity leading to reduced fitness.	• Reduced productivity of fisheries (especially in shallow water); Turbidity can cause abrasion of fish gills, interfere with migration, and increase predation on juvenile fishes. • Destruction of nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Damage or disturbance to sensitive benthic habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Interference with and exclusion of traditional, recreational and commercial fishers and tourism operators.	Avoid	At site selection design stage, avoid the placement of shipping lanes and dredging zones in sensitive marine habitat including areas identified as important for fishing and cultural importance. Ensure site selection is informed by an analysis of the oceanography of the dredging zones, and plume model studies[95].
				Avoid	Develop exclusion zones for port construction and operations in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Establish a dredge management plan that outlines measures to minimise impacts and suitable management responses when trigger values for marine water quality are exceeded; i.e. findings of the water quality monitoring program should be used to determine water quality parameters for the Dredge Management Plan and trigger levels for each parameter above which work practices will need to be reviewed or suspended.
				Minimise	Investigate the use of dredging equipment and techniques that will limit the impact on the relevant habitats or species. For example the use of Cutter Suction Dredger type dredger may reduce the mobilisation of fine sediment in an area in close proximity to marine communities that are sensitive to increases in turbidity.
				Minimise	Use a silt curtain/screen to control suspended solids resulting from dredging operations. A silt curtain is an 'impermeable device for control of suspended solids and turbidity in the water' column such as a floating vertical barrier. A silt screen is a flow-through filtering device created with permeable geosynthetic fabrics which filter water and reduce water pressure on the device[137,138].
				Minimise	Reduce footprint, duration and volume of dredging to the minimum required. For example locating jetty structures in deeper water to reduce the need to undertake capital and maintenance dredging of shipping channels.
				Minimise	Consider timing of operation to avoid or minimise environmental effects. Seek guidance at the earliest stages from environmental agencies, on most appropriate times to undertake dredging to avoid or minimise disturbance to marine features[139].
				Minimise	Manage sediment loading and deposition processes to minimise suspended sediment. Alter the time of year of dredging and disposal to reduce impacts on sensitive benthic and pelagic communities and / or critical life phases, e.g. coral spawning, whale calving Use specialised dredging equipment, e.g. turtle excluding devices.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.
Dredging Disposal of dredge spoil.	Displacement of benthic habitat and increased suspended sediment in water column.	• Destruction of valuable marine habitats, e.g. seagrass or coral. • Destruction of habitat for benthic and burrowing species. • Increases in suspended sediment lead to reduced primary production through reduced light levels, disrupting food webs. Increased sediment deposition on sensitive habitats such as coral reefs Burial of sessile organisms unable to cope with sediment deposition.	• Reduced productivity of fisheries (especially in shallow water); turbidity can cause abrasion of fish gills, interfere with migration, and increase predation on juvenile fishes. • Destruction of nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Damage or disturbance to sensitive benthic habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering).	Avoid	At site selection stage avoid or minimise placement of spoil deposition in zones of sensitive marine habitat and areas identified as important for local fisheries or cultural significance. Site selection should be informed by an analysis of the oceanography of the spoil deposition zones and plume model studies.
				Avoid/ minimise	Undertake options analysis for the location of spoil disposal. Consider the option of placing dredge onshore when port infrastructure is located in close proximity to marine protected areas. Consider alternative uses for dredge material including: land reclamation, beach nourishment, offshore berms, capping material, agriculture, environmental habitat restoration - keeping it within the local sedimentary system[139]. iv
				Minimise	Minimise the extent of the dredge spoil disposal area.
				Minimise	Outline measures to identify and address the re-suspension of marine sediments containing harmful compounds such as tributyltin (TBT). Analysis of benthic sediments should be undertaken prior to dredging activities and measures established for safe disposal /containment[139].

Source of impact & application in phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Noise Underwater noise caused by port construction activities including dredging, drilling, pile driving and shipping.	Underwater noise generated in the marine environment.	• Impacts of noise on marine mammals may be behavioural or physiological. • Behavioural impacts for marine mammals include changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant relationships, masking of biologically important sounds and avoidance of the noise sources[104]. • Physiological effects of underwater noise may include a reduction in animal hearing sensitivity or secondary effects associated with other systems including the vestibular system, reproductive system, nervous system and liver[104]. • Noise emissions that interfere with natural sounds in the marine environment may affect the timing of social and reproductive behaviour[105], particularly if the disturbance to vulnerable or endangered animals coincides with very short breeding or spawning periods. This could result in reduced breeding success and possible mortality. • Impacts to communication in marine mammals and other marine organisms.	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through presence of noise and vibration. • Altered behaviour of species of economic (e.g. commercial fish)or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Avoid	Determine what species are likely to be present in an area before commencing port construction. Undertake activities outside of sensitive lifecycle periods for relevant species, such as migration, breeding, calving and pupping.
				Minimise	Qualified marine mammal observer on board in high risk habitats. To prevent a startle response from marine fauna, undertake observations around piling operations prior to commencement of work. If species are observed within a site specific exclusion zone delay commencement until individuals clear the area. Only commence surveys during daylight hours when visual mitigation is possible. v
				Minimise	Use soft start procedures for piling operations and dredging whereby the source level is increased gradually before use at full power. The expectation is that nearby animals respond by avoiding the sound source[141].
				Minimise	Use suction pile installation for piling activities (quieter) if possible[109].
				Minimise	Ensure gradual start-up of engines and thrusters where possible, to provide opportunity for species to take evasive action[107].
				Minimise	Propeller and thruster noise: Many options for reducing noise from propellers and thrusters currently exist and have been implemented on a large number of commercial vessels. These include good propeller design, including large diameter, slow turning props (reduced cavitation), as well as blade shapes optimised to flow conditions, increased skew, and hull modifications to improve flow conditions. Cold ironing (or shore connection, alternative maritime power (AMP)) should be carried out when ships are at berth[108,109].
				Minimise	Use sonar equipped with transducer operating frequency above 200kHz to minimise interference with marine mammals[142].
				Minimise	Use hydrophones to monitor underwater noises from relevant sources. Implement noise reduction measures (non-essential equipment shut down) when cumulative noise load exceeds 120dB@ 250m from vessel (120dB is the threshold at which Mysticeti whales are thought to avoid feeding and breeding activities. US Federal Register 70 FR 1871, 71 FR 3260, and 73 FR 41318)[108].
Hazardous materials Planned or accidental release of toxic and non-toxic substances during port construction and operational activities.	Discharge of hazardous materials (hazmats) to marine environment. Hazmats can be classified according to the hazard as explosives, compressed gases, including toxic or flammable gases, flammable liquids, flammable solids, oxidizing substances, toxic materials, radioactive material, and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from hazardous substances or increased turbidity (especially in shallow water). • Impacts on regulating and maintenance services through impacts on the phyico-chemical conditions of the water column from contaminants. • Impacts to human health and nutrition due to chemicals bio accumulating and affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through direct mortality from chemical incidents or alteration of marine environment. • Potential to inundate waste assimilation services thereby reducing this function.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only.
				Minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines should be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning port infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Install permanent 'scrub-off' facilities to collect maintenance residues from operational areas.
				Minimise	Develop a surface water management plan to limit risk of chemicals entering the marine environment, e.g. contain and collect surface water from maintenance areas and test and treat before releasing to the marine environment.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their MSDS. Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.

iv Aerial exposure of certain soils can lead to the production of sulphuric acid and the release of toxic quantities of iron, aluminium and heavy metals[140].
v For example, a minimum distance of 350 m in water deeper than 3 m and 150 m in water shallower than 3 m was documented for the Gladstone LNG project.

4.5. Seismic surveys

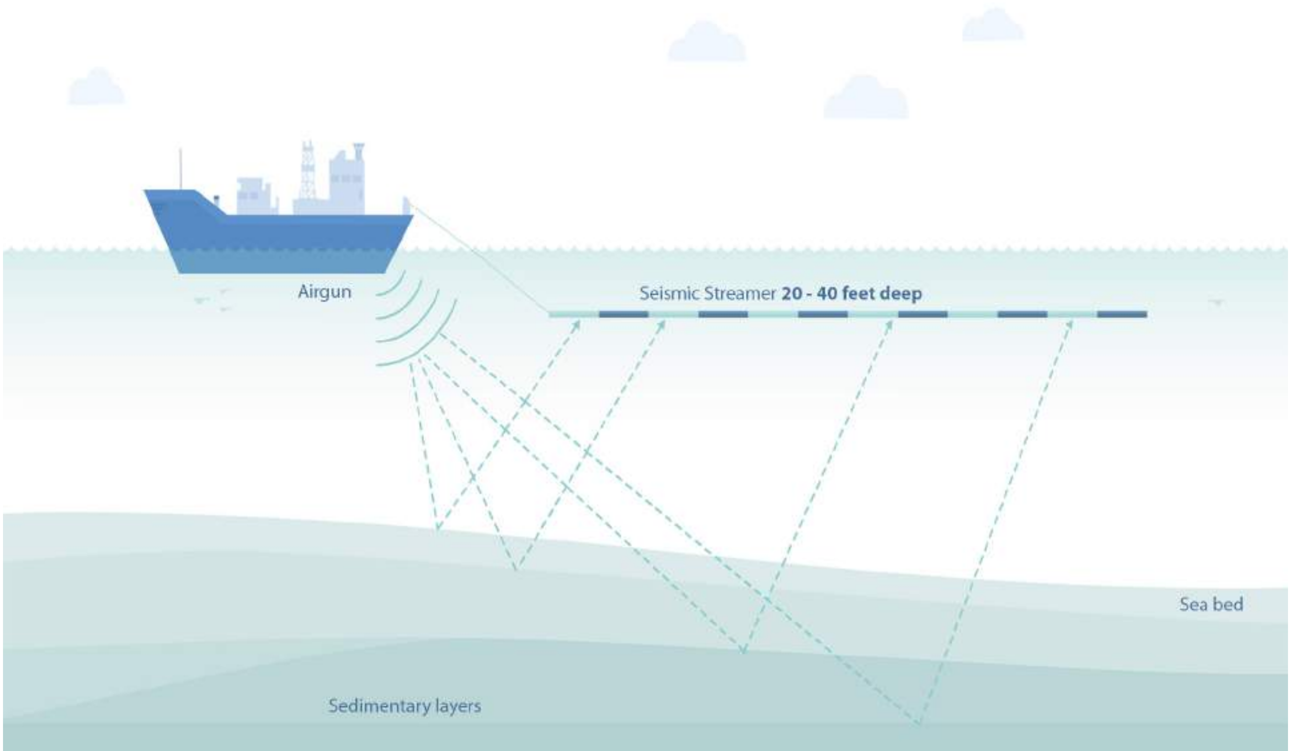
Oil and gas explorers use seismic surveys to produce detailed images of the various geological strata and their location beneath the Earth's surface to determine the location and size of oil and gas reservoirs.

Credit: Woodside Energy Ltd

During seismic surveys sound waves are bounced off underground rock formations and the waves that reflect back to the surface are captured by recording sensors (Figure 9). Analysing the time the waves take to return provides valuable information about rock types and possible gases or fluids in rock formations. This is similar to the use of ultrasound in medicine.

In marine operations, a specialised vessel tows a "seismic streamer", or a collection of cables with seismic sources and hydrophones attached. The seismic sources use compressed air (air guns) to produce acoustic energy. The hydrophones capture the returning sound waves. Sufficient scientific data exist to conclude that seismic airguns used in geophysical exploration have a low probability of directly harming most marine life, except at close range where physical injury is a real danger. While the use of airguns does not appear to disturb animals in some circumstances, in other conditions it can result in moderate to extreme behavioural responses and/or acoustic masking over large areas[143,144,145,146]. Planning strategies for managing the risks posed by seismic and other surveys are discussed in Box 12.

Figure 9. Seismic surveys



Box 12: IUCN's effective planning strategies for managing environmental risk associated with geophysical and other imaging surveys

The IUCN has produced a practical guide to responsible and effective planning of offshore geophysical surveys and other forms of environmental imaging. It offers a structured, systematic evaluation and decision-making framework for industry, regulators, and scientists. The basic elements, structure, and sequence of this framework are adapted from Nowacek et al. (2013)[145]. While the focus here is on marine mammals, this process can be applied in any situation involving protected and sensitive species (PSS).

The process presented in the IUCN document begins with pre-survey screening of proposed activities and the local environment, and then moves into a series of practices for planning, implementation, and evaluation of mitigation and monitoring activities.

Pre-survey screening

Before any practices are begun, an initial overarching risk assessment of the general nature of the survey activity and the local environment is necessary to help determine the scale and magnitude of effort that will be required. This involves assessing the type, scale, duration, and specifics of the proposed survey, as well as the environmental features and potentially affected species within the survey area.

Practice #1. Assess the environment in the context of the proposed action

Once pre-survey screening has been completed, the next step is to conduct an appropriately scaled evaluation of the environment in which the proposed survey would take place. This might involve a review of existing data, if it is a well-studied area, or additional collection of baseline environmental data, if the area is relatively unexamined. The elements of this practice include:

- **collection of baseline environmental and biological data (biotic and abiotic features of the ecosystem)**, including the identification and evaluation of multi-year data on protected or sensitive species and other species that may be impacted, ecosystem features, and physical aspects of the environment;
- **identification of proposed actions and alternatives**, including sound output parameters from seismic sources; sound propagation and exposure modeling tools, algorithms, and assumptions; and alternatives that could minimise overall exposure of PSS to sound; and
- **stakeholder engagement**, including consultation and collaboration with individuals, non-governmental organisations, or government agencies that may have an interest in or be affected by seismic activities.

Practice #2. Evaluate risk and develop plans

Following from the assessment of the environment and the proposed operation conducted in Practice #1, the next step is a structured risk assessment to determine the magnitude of potential impacts from the survey activity. The elements of this practice include:

- **evaluation of risks of proposed actions and alternatives**, based on survey characteristics, and environmental and biological/ecological characteristics. This evaluation should include an exposure analysis, evaluation of potential acute and chronic effects, and an assessment of estimated response probability for affected species;
- **identification of mitigation actions**, including specific mitigation objectives, operational protocols for the detection of PSS, and training and coordination for relevant personnel; and
- **development of monitoring strategy and methods** for application before, during, and following operations. Monitoring protocols should be developed for all PSS and integrated with real-time mitigation, and should include a comprehensive reporting plan.

Practice #3. Implement mitigation and monitoring of operations

This step involves implementation of the mitigation and monitoring plan developed in Practice #2. The elements of this practice include:

- **operational implementation of mitigation measures**, giving consideration to the timing of the survey and source characteristics;
- **implementation of real-time mitigation**, including written protocols and a dedicated effort by properly trained personnel; and
- **implementation of monitoring protocols with data validation and archiving**, to allow for effective post-survey reporting and evaluation.

Practice #4: Evaluate and improve

Assessment and evaluation should begin at the conclusion of operations, with the twin aims of presenting a thorough evaluation of the efficacy of the monitoring and mitigation plan, and developing lessons learned to be incorporated into future monitoring and mitigation programmes. It is important that results and analyses from monitoring and mitigation be made available as openly as possible, to all stakeholders and interested parties. Elements of this practice include:

- **reporting on effectiveness of the mitigation programme**, including an overview of operations, effort, effective implementation of mitigation measures, any major events, initial data analyses, and short- and long-term plans for analyses;
- **review of effectiveness of the monitoring programme**, to allow for improvement in future mitigation methods; and
- **prompt analysis and availability of results**, to help inform future risk assessments and mitigation and monitoring efforts, and to identify and fill data gaps to support future activities and exploration of the ecosystem.

The full document and its Annex of resources can be downloaded from the IUCN Library System online https://portals.iucn.org/library/node/46291
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Table 3: Impacts associated with seismic surveys on marine biodiversity and ecosystem services, and recommended activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping In support of seismic surveys.	See 'Shipping' table for potential impacts and mitigations relating to shipping.				
Airguns Used in seismic arrays as part of exploration.	Sound generated in the marine environment through use of airgun.	Impacts on fish: • Auditory masking: sound generated by seismic airguns masks the presence of sounds that are biologically relevant to fish, e.g. sound of predators, prey, mates. Can impact survival, communication, navigation etc.[147] • Temporary Threshold Shift - temporary loss of hearing sensitivity through damage to the sensory cells of the inner ear. Can result in reduced fitness until normal hearing returns[147]. • Can cause haemorrhages and brain and hearing damage if close to the airguns[148]. • Scaring effects in fish can result in a change in swimming pattern[119]. • If seismic surveys are carried out during migratory periods, shoals may lose track of their migratory path. During such periods, shoals may become dispersed, resulting in smaller groups of individuals that can become easier prey for predator[119].	• Impacts on provisioning services due to disruption of species important for commercial and subsistence fisheries.	Avoid / minimise	Assess and evaluate the environment (especially sensitive features) in the context of the proposed action, including viable alternatives. Complete a risk assessment and develop a survey plan incorporating mitigations and M&E[146]. i
				Minimise	Determine what species, especially shoaling fishes, are present in an area before commencing seismic surveys and assess if there are any seasonal considerations that need to be taken in to account, such as important migration, rearing or spawning, which can be avoided in space and time[149]. There should be access to multi-year baseline data on the ecology of key species, including seasonal occurrence and density, behaviour, reproduction, foraging, and habitat use is needed to guide survey planning and the design of appropriate mitigation[146]. ii
				Minimise	Use soft-start techniques for surveys whereby sound is emitted at low levels initially and is slowly built up over a period of (e.g.) 20-30 minutes until it reaches the intensity required during seismic activity. This gives marine life more chance to move away[149].
				Minimise	Use the lowest practical acoustic sound pressure level for the survey that will still achieve survey objectives[153].

i IUCN's 'Effective planning strategies for managing environmental risk associated with geophysical and other imaging surveys' provides step-by-step advice on managing environmental risk .
ii The E&P Sound & Marine Life Joint Industry Programme (JIP) supports research to help increase understanding of the effect of sound on marine life generated by oil and gas exploration and production activity[150].
A good example of long-term monitoring of marine species of concern is the Angola LNG project which teamed up with Wildlife Conservation Society to undertake multi-year monitoring of key species , including cetaceans, ahead of project development[151].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Airguns Used in seismic arrays as part of exploration.	Sound generated in the marine environment through use of airgun.	Impacts on cetaceans and marine reptiles: • Auditory masking which can result in impacts to feeding, navigation, communication and behaviour[152]. • Behavioural changes can include changes to diving patterns, ceasing of vocalisation, changes to breeding and changes to migratory regimes. • Abandonment of important habitats such as calving and nursery sites following repeated acoustic disturbance • Temporary or permanent loss of hearing • Stress, resulting in impacts to immune system, reproductive health or behaviour.	• Impact to cultural ecosystem services linked to ecotourism (whale and turtle watching, existence value).	Avoid	Schedule seismic surveys for time periods when cetacean activity is known to be low[146]. iii
				Avoid	Establish mitigation zones, e.g. 1.5km radius for species of concern with young, 1km for species of concern without young, and 500m for all other species. The acoustic source must be shut down if any marine mammals enter the relevant mitigation zones[153]. iv
				Minimise	Use the lowest practical acoustic sound pressure level for the survey that will still achieve survey objectives[153].
				Minimise	Determine what species are likely to be present in an area before commencing seismic surveys and assess if there are any seasonal considerations that need to be taken in to account, such as migration, breeding, calving and pupping[149,150]. Ideally there should be access to multi-year baseline data on the ecology of key species, including seasonal occurrence and density, behaviour, reproduction, foraging, and habitat use is needed to guide survey planning and the design of appropriate mitigation[146]. v
				Minimise	If marine mammals are likely to be present in an area, only commence surveys during daylight hours when visual mitigation using Marine Mammal Observers (MMOs) is possible. If marine mammals are spotted, operations should be suspended immediately. MMOs should be independent and should have the authority to suspend surveys immediately[149].
				Minimise	If carrying out seismic surveys in darkness or low visibility, use a Passive Acoustic Monitoring device (PAM) to detect marine mammals likely to be present in the area. PAM operatives should assess any acoustic detections and determine if there are likely to be marine mammals within 500m of the source. If present, the operation should be suspended[149].
				Minimise	Use Active Acoustic Monitoring (AAM) to supplement visual observations and PAM as mitigation measures. AAM can detect animal presence in all conditions regardless of whether animals are vocalising, and should supplement visual observations and PAM to ensure that operations can commence under low visibility conditions[150].
				Minimise	Conduct pre-seismic shooting search for marine mammals before a soft-start technique is undertaken (see minimisation activity below)[149]. A search should be conducted 30 minutes before firing of the seismic source or 60 minutes if surveying where deep diving mammals are likely to be present (in deep waters >200m). If marine mammals are detected within 500m of the centre of the airgun array during the pre-shooting search, the soft-start of the seismic sources should be delayed until they are more than 500m away from the source, and there should be a 20 minute delay from the time of the last sighting within 500m to commencement of the soft-start.
				Minimise	Use soft-start techniques for surveys whereby the noise volume is slowly built up over a period of (e.g.) 20-30 minutes to give marine life more chance to move away[149].
				Minimise	If firing of the airguns has stopped and not restarted for at least 10 minutes then a pre-shooting search and 20 minute soft-start should be carried out.
				Minimise	Address information gaps on the effects of underwater sound upon marine mammals and reptiles including investigation of physiology, anatomy and behavioural responses, and retrospective assessment of historical stranding events[154]. vi

iii An example of this comes from Sakhalin Energy, for which the primary mitigation tool was to conduct the survey as early in the season as possible - at a time when the fewest whales were expected to be present.
iv Mitigation zones are required by law in some countries, e.g. New Zealand.
v A good example of long-term monitoring of marine species of concern is the Angola LNG project which teamed up with Wildlife Conservation Project to undertake multi-year monitoring of key species ahead of project development.
vi The impacts of seismic surveys on turtles is not well understood, and requires further investigation.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Acoustic receivers (streamers) Acoustic receivers (streamers) are used in seismic arrays.	Streamers extend off the back of the seismic vessel.	• Marine animals can become entangled in the seismic streamers. This can affect organisms such as marine reptiles, sunfish and mantas and lead to direct mortality of individual animals.	• Impact on provisioning and cultural services (diving, ecotourism) through direct mortality and disruption of the food web.	Minimise	Reduce potential for entanglement of marine animals in the seismic equipment by including no tangle gear attached to the streamers[155]. vii
				Minimise	Create plans for rescue and release of tangled organisms.

vii The effectiveness of no tangle gear requires further investigation

4.6. Exploration drilling

Drilling is the process of creating a bore hole or well in the Earth's crust to test for and extract oil and gas. Drilling for exploration and production is essentially the same process – what differs is that a well that is used for production would be completed and connected to different equipment above the surface. These processes are covered in the 'Field Development' section.

Credit: Woodside Energy Ltd

During exploration, a well is created by drilling a hole (12 – 100cm in diameter) into the earth with a drilling rig. A drill bit cuts into the rock and is attached to the end of the pipe or drill string. This string is gradually lengthened as the well gets deeper by screwing in additional sections or "joints" of pipe.

Drilling fluid or "mud" is pumped down the inside of the drill pipe and exits at the drill bit. The principal components of drilling fluid are water and clay, but it also typically contains a complex mixture of fluids, solids and chemicals mixed for the conditions of the rock. The drilling mud cools the drill bit, lifts rock cuttings to the surface and prevents destabilisation of the rock in the well walls. The generated rock "cuttings" are carried back to the surface by the drilling fluid which then goes through "shakers" to separate the cuttings from the mud, which is returned to the bit. The cuttings are usually discarded close to the borehole.

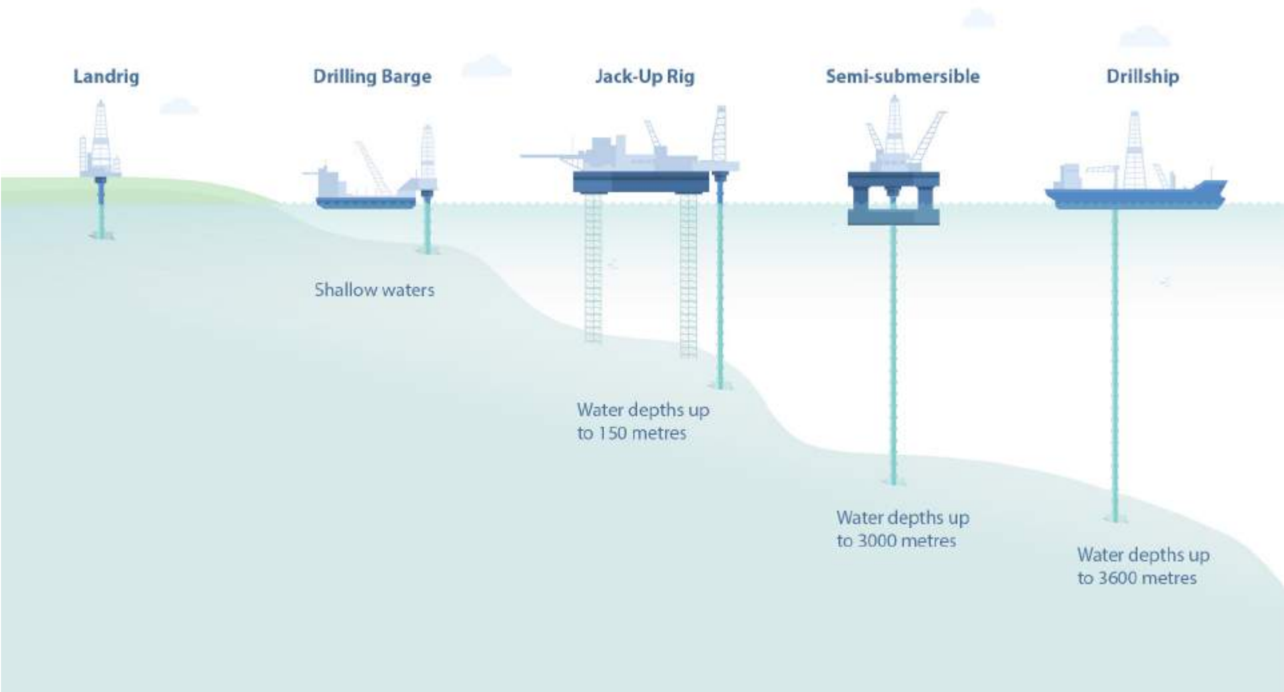
During or after the hole is drilled, sections of steel pipe called casings, slightly smaller in diameter than the borehole, are placed in the hole. They are cemented in place by injecting cement into the well which fills out and around the casing. The casing provides structural integrity to the newly drilled well, and also isolates potentially dangerous high pressure zones from each other and from the surface.

Different drill rigs are used depending on the depth of the marine environment. In shallower water of up to 100m a jack-up drill rig is typically used. This type of rig is mounted on a barge which is towed into place. Legs extend to the sea floor and then the barge lifts out of the water, becoming a stable drilling platform (Figure 10).

In rougher seas or water up to 3000m deep a semi-submersible drilling rig is used. This platform is attached to submerged pontoons. When the pontoons are flooded with water they lower into the ocean, creating a counterbalance and reducing the effect of waves . Semi-submersibles are held in place by large anchors or by dynamic positioning systems, which use computer-controlled propellers to keep the ship in the correct place.

In deepwater situations a drill ship is used. This is the largest and most expensive of options. Drill ships may be held in place by anchors or by dynamic positioning systems.

Figure 10. Examples of different drill rigs used in differing depths of water



Box 13: Drilling around cold-water corals in Norway.

Two production oil fields on the Norwegian Continental Slope are in areas of abundant cold-water corals[156,157,158]. Exploration drilling has occurred near the Pockmark-reefs at the Kristin field and the reefs of the Morvin field since 1997[159] and 2001 respectively (production began at 2005 and 2010 respectively). Drilling in the vicinity of corals has the potential to lead to effects from direct mechanical damage, exposure to waste drilling and production products and acute exposure to accidentally released hydrocarbons[160,161].


Credit: Daniel Jones

The location of corals is determined in Norway by a statutory detailed site survey prior to drilling and direct damage is avoided by positioning drilling and anchoring points away from corals. The release of cuttings is tightly controlled in Norway, with only water-based low-toxicity muds being used[162]. These are still likely to lead to damage to coral communities[163,164]. As a result, at Morvin, novel infrastructure (cutting transport system) was developed to transport drilling discharges 500 m from the well[165], a distance predicted by cuttings dispersion models[166] to lead to low sedimentation levels on corals. In addition, a detailed monitoring programme was put in place to assess potential impacts and effects to the reef, which included sediment sampling, video observations, sensors and sediment traps[167,168].

The results of these mitigation measures appear to have been generally successful. Although concentrations of drill cuttings in excess of 25 ppm, which may impact negatively on *Lophelia pertusa* growth[164], were observed briefly on several of the monitored reefs, no impacts were reported to the coral communities[165]. The impacts of produced water are not well known[169]. Soft sediments adjacent to the drilling activity were also assessed and impacted to a distance of over 100m from the well, although the effects were greatly reduced after three years[170]. The research stimulated by these drilling events has informed industry modelling protocols[164,171] and policy[172].

Table 4: Impacts associated with exploration drilling on marine biodiversity and ecosystem services, and recommended activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping In support of drilling activities.	See 'Shipping' table for potential impacts and mitigations relating to shipping				
Temporary drill rig Presence of drill rig in marine environment.	Minor releases of pollutants/wastes from rig. Non-physical disturbance such as noise & visual presence. Potential for rig to promote fish aggregation (act as a Fish Aggregation Device (FAD)).	• Disturbance to migration, feeding and breeding patterns through noise and light from vessel, e.g. where rig is adjacent to intertidal areas used by migratory birds • Increased abundance of marine life in area surrounding rig.	• Potential for increase in fishing around rig[173], but with restricted access for traditional and commercial fishers. • Potential for drilling staff and contractors to fish or purchase illegal fish products. • Provisioning services impacted due to restricted access to traditional and commercial fishing grounds for the period of drilling (usually 2-6 months). • Impact on provisioning services through altered behaviour of species important to commercial and local fisheries due to attraction of species to the rig, temporarily increasing abundance around the rig and reducing abundance of fish in surrounding fishing grounds with implications for livelihoods and nutrition. • Impacts to cultural services (e.g. ecotourism, whale watching, reef diving) related to the presence of drill rig. • Visual and aesthetic impact to seascape. • Indirect loss of cultural ecosystem service values from loss of sense of place through impacts of light and noise and visual disturbance.	Avoid	Where resource lies beneath an area of high BES sensitivity, consider using directional drilling to locate drilling rig in a less sensitive area. i
				Avoid	Develop exclusion zones for drilling operations in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Control workforce activities - prohibit workforce from fishing and coral collection.
				Minimise	Report all illegal fishing in vicinity of platform to authorities.
				Minimise	Ensure Company and contractor employees are contractually prohibited from trade with illegal fishers, including for protected and endangered or rare species used by local communities for subsistence.
				Minimise	Wherever possible, place rigs and route sea vessels out of visual range of areas important for ecotourism, reducing the overall visual impact on the marine environment.
Anchors Anchors and anchor chains that are deployed for temporary rig installation.	Disturbance of small area of sea-floor by anchor, and wider disturbance by anchor chains as they are tightened, re-disturbing the sea-floor area.	• Death of marine species by crushing by anchors and anchor chains. This could affect sessile or slow-moving benthic organisms that are not able to move away from the area where the anchors are lowered. • Disturbance/removal of marine habitat and displacement of marine species. • May cause some disturbance through noise and vessel movements, particularly adjacent to intertidal areas used by migratory birds[87].	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Impacts to sensitive seafloor habitats, such as cold-water coral ecosystems or sponge aggregations. • Impacts to physico-chemical conditions of the water column from turbidity related to lowering legs of the anchor platform with potential impacts on regulation and provisioning services of the water column.	Avoid	Where resource lies beneath an area of high BES sensitivity, consider using directional drilling to locate drilling operation in a less sensitive area.
				Avoid	Use dynamic positioning to avoid the need for anchors.
				Avoid	Site selection – locate drilling operations away from sensitive inshore marine species and habitats for BES.
				Avoid	Avoid lowering anchors on to hard substrate; use ROVs before lowering anchors to ensure anchors do not impact deepwater coral colonies and other sensitive species. ii
				Avoid / minimise	Ensure drilling is carried out by companies with a good environmental track record. These should have demonstrably effective policies on minimising environmental impacts taking into account national and international standards, ensuring the protection of the environment.

i The Exxon-Neftegas Limited (ENL) development in eastern Russia (Sakhalin-I) uses assets on shore to drill wells to reach and extract oil and gas from deposits 5 to 10 km offshore[146]. In the UK directional drilling has been used to recover oil and gas from the largest onshore oil field in Western Europe at Wytch Farm, Dorset[174], which lies beneath the Jurassic Coast World Heritage Site.
ii Displacement of marine species from rig anchoring is dependent on the duration of the drilling program, which typically varies from two weeks to two months[175].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Temporary drill rig Ballast water exchange: water used as a ballast to stabilise rig at sea.	Discharge of ballast water from rig's hull in different location to where it was pumped in can result in the introduction of alien species into the marine environment. Alien species can include bacteria, microbes, small invertebrates, eggs, cysts and larvae of various species, and can become established in their new environment to become alien invasive species (AIS) under certain conditions. Impacts from AIS offshore can be transferred to coastal areas in currents and tides.	• Decline or extinction of native species through AIS competing with native species for space and food. • Decline or extinction of native species through AIS preying upon native species Decline or extinction of native species through introduction of diseases and pathogens. • Alteration of habitat. • Alteration of environmental condition, e.g. decreased water clarity. • Alternation of food web dynamics through reduction in and removal of key populations.	• Impacts for provisioning services if introduced diseases and AIS overwhelm fish and other species important to commercial or subsistence fisheries.	Avoid	Ensure the ports used have facilities to receive and treat ballast water to manage in an environmentally safe way sediments of the ballast tanks and eliminate all organisms and pathogens.
				Minimise	As per the Ballast Water Management Convention ships (including rigs) in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. The Ballast Water Management Plan is specific to each ship and includes a detailed description of the actions to be taken to implement the management requirements and practices[97,98,99]. All ships must also carry a ballast water record book to record when ballast water is taken on board; circulated or treated for Ballast Water Management purposes; and discharged to sea. It should also record when ballast water is discharged to a reception facility and accidental or other exceptional discharges of ballast water. Ships must also carry an international ballast water management certificate[97].
				Minimise	Wherever possible ballast water should be taken on-board outside of port waters and as far away from the coast as possible[97,98,99]. The uptake of ballast water should be minimised or, where practicable, avoided in areas and situations such as: - In darkness when organisms may rise up in the water column - In very shallow water - Where propellers may stir up sediment - Areas with current large phytoplankton blooms - Nearby sewage outfalls - Where a tidal stream is known to be more turbid - Where tidal flushing is known to be poor - In areas close to aquaculture - Where dredging is or recently has been carried out
				Minimise	Tanks used for holding other purposes (e.g. grey water, treated sewage) should be cleaned prior to use for holding ballast water.
				Minimise	Ballast water should be treated through either solid-liquid separation (the separation of suspended solid material, including the larger suspended micro-organisms, from ballast water either by sedimentation or by surface filtration) or by disinfection (removes and/or inactivates microorganisms through chemical inactivation, physiochemical inactivation or asphyxiation)[100]. Solid-liquid separation processes produce a waste stream which required appropriate management and during ballasting they can be safely discharged at the point where they were taken up.
				Minimise	Under Regulation B-4 of the Ballast Water Management Convention, all ships/rigs using ballast water exchange should, whenever possible, conduct ballast water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth, taking into account guidelines developed by IMO. In cases where this is not possible, ballast water exchange should be conducted as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth[97]. When these requirements cannot be met, platforms should conduct ballast water exchange in designated area, or conduct tank-to-tank transfer of ballast water to prevent discharge of high-risk ballast water to the marine environment.
				Minimise	All rigs should remove and dispose of sediments from spaces designed to carry ballast water in accordance with the provisions of the rigs' ballast water management plan[97].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Temporary drill rig Biofoulants on drill rigs.	Transportation of biofoulants that attach to drill rig into non-native environments. Can include large colonies of stony corals, which likely harbour many species and can act as a vector for AIS.	• Decline or extinction of native species through AIS competing with native species for space and food. • Decline or extinction of native species through AIS preying upon native species. • Decline or extinction of native species through introduction of diseases and pathogens. • Alteration of habitat. • Alteration of environmental condition, e.g. decreased water clarity. • Alteration of food web and the overall ecosystem.	• Impacts for provisioning services if AIS negatively affect fish and other species important to commercial or subsistence fisheries.	Minimise	Ensure vessel(s) have a documented Biofouling Management Plan[99,101,102].
				Minimise	Investigate all technologies to reduce biofouling - follow, for example, best practice in prevention and management AIS in the oil and gas Industry[99].
				Minimise	Apply hot water treatments to reduce biofouling (including "thermal shock" and Hull Surface Treatment)[103].
				Minimise	Develop biofoul risk assessment and quarantine management system for all operational vessels and supply tankers.
				Minimise	Ensure anti-fouling treatment records are up-to-date.
Temporary drill rig Artificial lighting used on rig.	Light emitted from the drill rig causing light pollution in the marine environment.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight, condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • If fish are attracted to light source, it could result in increase in predation of fish aggregated around sea vessel. • Artificial lighting can result in avoidance of nesting beaches by marine turtles and can impact on the ability of hatchlings to orientate after leaving the nest[127]. • Artificial lighting may disrupt and disorient sea birds. For example petrel fledglings are known to be attracted to light sources and are subsequently grounded leaving them vulnerable to other threats[129]. iii	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to light disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Minimise	Keep artificial lights to the minimum required to meet navigation and operational safety requirements[112]. For example, install security lights on motion-sensitive switches.
				Minimise	Filter and/or shield lights in order to decrease light intensity for example use hoods and covers to reduce the amount of light spilling[130].
				Minimise	Redirect lighting away from sensitive habitats such as nesting beaches and wetlands adjacent to the drilling site.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing the attraction by migratory birds and turtles[113]. For turtles use light sources that are 'turtle friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium vapour lighting is the purest yellow light source and recommended due to being the best commericially available solution.
				Minimise	Make personnel working on site aware of threatened and migratory species that may be grounded as a result of artificial lighting.

iii The extent of impact will depend on the extent to which sensitive species become accustomed to noise and illumination at night. For example, migratory birds have been known to forage and roost in close proximity to existing port developments.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Machinery, propellers and thrusters Used for exploratory drilling.	Noise generated in the marine environment through operation of machinery, propellers and thrusters. Strikes to fish, marine mammals etc. from moving equipment.	• Reduced ability of marine mammals to communicate, detect natural sounds, and navigate. • Avoidance behaviour. • Physical damage to hearing and/or tissues and organs. • Interference with cetaceans' range, inducing stress. • Reduction in breeding and feeding success of marine mammals. • Reduced habitat suitability for seabird populations, resulting in reduced feeding success.	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impacts of noise and vibration. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals, sea birds) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Minimise	Determine what species, especially shoaling fishes, are present in an area before operating machinery and assess if there are any seasonal considerations that need to be taken in to account, such as important migration, rearing or spawning, where delay of activities could be considered[112].
				Minimise	Use Passive Acoustic Monitoring to determine if any sensitive species (e.g. marine mammals or turtles) are within 500m of intermittent based sound source (for example from explosives or impact pile-driving) and if present, suspend work if above noise load exceeds 120 dB @ 250 m from drill rig[110].
				Minimise	Propeller and thruster noise: Many options for reducing noise from propellers and thrusters currently exist and have been implemented on a large number of commercial vessels. Good propeller design, including large diameter, slow turning props (reduced cavitation), as well as blade shapes optimised to flow conditions, increased skew, and hull modifications to improve flow conditions are effective ways to reduce underwater noise. Cold ironing, or shore connection, or alternative maritime power (AMP), will help to reduce noise when ships are at berth[108,109].
				Minimise	Vibration from large machinery such as power generation and propulsion equipment. Selection of inherently quiet machinery is the best option for noise reduction as this results in essentially no additional weight or space. Resilient mounting of machinery is a relatively low cost method of achieving significant reductions in underwater noise caused by machinery vibration[108]. iv
Drilling muds, fluids, cuttings and cement Drilling requires the use of drilling muds. Drilling generates fluids and cuttings.	Drilling cuttings, cement, muds and other fluids may be released to the environment during drilling operations.	• Smothering of organisms under the mud/cuttings pile. Reduced ability to feed, leading to ill health and death of sessile (immobile) species unable to move. • Change in environmental conditions on the seafloor, such as changes in grain size and reductions in the thickness of oxygenated sediment layers, may lead to major ecosystem effects. • Movement of marine organisms in response to drilling may require substantial energy investment that could influence survival and reproductive success. • Chemical toxins (e.g. hydrocarbons, heavy metals) present in drill mud (and cuttings) may lead to adverse environmental effects.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to loss of habitat quality and changing physico-chemical conditions of the water column from contamination by mud, cuttings and chemicals. • Impacts on supporting services that provide for marine species lifecycles (e.g. spawning) through loss of habitat quality. • Impacts on regulating and maintenance services (such as assimilative services) through impacts on the physico-chemical conditions of the water column from contamination by mud, cuttings and chemicals. • Impacts to human health and nutrition due to chemicals bio accumulating and affecting the health of fish caught and consumed.	Avoid	Avoid oil based muds in favour of water-based muds where possible and minimise discharge of non-aqueous fluids. Where necessary, use Group III non-aqueous drilling fluids at depths exceeding those suitable for water-based muds.
				Avoid	Recover or relocate top-hole cuttings through a Cuttings Transport System. Recover drilling muds through a Riserless Mud Recovery system which returns muds to the drill rig. v
				Avoid	Use modelling to predict how particles will disperse and be deposited on the seafloor (natural oceanic factors such as water depth, tidal current and the interplay of surface and oceanic currents can influence the dispersion and dilution rates of discharged wastes) and use results to avoid deposition onto hard substrate and sensitive deep water communities such as corals, sponges, etc., or use available technology to transport cuttings away from vulnerable resources (e.g. Cutting Transport System)[167]. Avoidance of deposition on sensitive deep water communities and colonies around seabed fluid flow environments, such as cold seeps, should be considered a priority[180,181].
				Minimise	Perform visual mapping (e.g., remotely operated vehicle - ROV surveys) and minimise drilling in areas with hard substrate and/or sensitive deep water communities (e.g., deep water corals, sponges, etc).
				Minimise	Separate water from contaminants and heavy particulates. Consider options for on-shore disposal.
				Minimise	Reduce use of any / all toxic chemicals used at various stages of work where possible.
				Minimise	Where oil based muds must be used, apply all International Association of Oil & Gas Producers (OGP) best practice for recycling all drilling fluids[179].

iv An example of selection of quiet machinery can be found in Sakhalin Energy's Marine Mammal Protection Plan[176].
v Cuttings transport system makes it possible for operators to deposit cuttings away from environmentally sensitive areas http://www.offshoreenergytoday.com/norway-eni-to-deploy-agrs-ctstm-on-goliat-field/

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Cooling water Used to cool drilling machinery.	Operational discharges of (heated) cooling water, resulting in changes to ambient water temperature (increased temperature).	• Decreased level of dissolved oxygen in water, potentially resulting in mortality of marine organisms. • May cause local thermal shock to temperature-sensitive organisms with limited mobility (e.g. eggs and larvae). • Heated waste water can stress corals and disrupt the composition and health of reef communities. Corals are particularly sensitive to thermal stress: temperatures increases of just a few degrees for extended periods can cause corals to bleach and die[182,183].	• Release of warm water impacts the physico-chemical conditions of the water column potentially impacting regulating and provisioning services through disruption of breeding of commercially important species, e.g. fish and shellfish. • Release of warm water linked to suppressed recruitment, e.g. in bryozoans and polychaetes[184]. • Thermal shock could reduce fitness of coral reefs, leading to adverse impacts to tourism.	Avoid	At site selection stage, locate outfall to avoid sensitive habitats.
				Minimise	Design discharge system to minimise thermal plume of discharged water.
				Minimise	Use modelling to predict how the thermal plume will disperse in the water column and use results to avoid fish spawning grounds.
				Minimise	Follow IFC guidelines (2008) for thermal discharge.
Organic waste Generated on drilling rig.	If sea vessels dispose of organic wastes (including kitchen waste, effluent, sewage and grey water) at sea, this could result in an increase in biological oxygen demand and a reduction in habitat quality[119]. Can result in eutrophication (algal blooms).	• In near-coastal waters or estuaries with poor flushing, organic waste can result in reduced benthos biodiversity and abundance, changes in fish behaviour, stress and acute or latent mortality of marine species through lack of oxygen. • May introduce pathogens and cause turbidity that would affect local sensitive organisms with limited mobility (benthos and eggs and larva).	• Impact to regulating service of waste assimilation through inundation of waste, leading to impacts on human health. • Impact on provisioning services through impacts to changing behaviour of nektonic and other species attracted to nutrients from waste. • Impact to provisioning services by increasing health risks from consuming commercial species, such as filter feeding shellfish. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column from increased nutrient levels and suspended matter.	Avoid	Treat all sewage and grey water (to recognised standards) prior to discharge OR no disposal at sea - disposal at port by reputable waste management contractors only[120].
				Avoid	Collect and compact all domestic waste for onshore disposal. Ensure detailed documentation and manifest-ing. Ensure that onshore receiving and disposal companies meet local and international requirements.
				Minimise	Use waste segregation at source for different types (organic, inorganic industrial wastes, etc.).
				Minimise	No disposal of untreated sewage or grey-water within 12 nautical miles of land[120].
				Minimise	Treat all sewage and grey water according to MARPOL requirements prior to discharge OR no disposal at sea - disposal at port by reputable waste management contractors only.
				Minimise	Store used cooking oils in suitably contained areas. Limit quantities stored to a minimum. Ensure detailed control documentation and manifesting for disposal.
Inorganic waste Generated on rig (e.g. plastics).	Staff on drill rigs could illegally dispose of inorganic waste at sea, resulting in pollution of the marine environment by waste, e.g. plastics. Potential for accidental discharge of waste during operations.	• Ingestion of plastic waste can cause individuals to die of starvation or malnutrition. Plastic waste ingestion has been linked to whale strandings[185]. • Diving birds can become entangled in plastic waste - can lead to infection, loss of limbs or death. • Plastic waste can leach toxic substances to sediments and water where it can be absorbed by small algae and animals and cause bioaccumulation in other animals feeding on them[115]. • Toxic plastics can be ingested directly by fish, exposing species further up the food chain to these pollutants - can lead to death from toxic poisoning[116]. • Habitat degradation (seagrass and coral reef) due to smothering and reduced light access.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality and disruption of food web caused by plastics. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impact to aesthetic beauty from plastic waste and direct mortality to species important to tourism. • Impacts to human health and nutrition due to health of fish caught and consumed[186]. • Impacts on regulating and maintenance services through impact on physico-chemical conditions of the water column due to turbidity.	Avoid	Do not dispose of plastic waste overboard; collect all plastic waste for onshore disposal by reputable waste management contractors only, and seek recycling options where available[117]. [vi]
				Minimise	Efforts should be made to eliminate, reduce, or recycle wastes at all times[118].

vi Overboard disposal of all types of solid waste from vessels is prohibited under MARPOL Annex V.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Hazardous wastes Planned or accidental release of toxic and non-toxic substances during exploration drilling.	Discharge of hazardous materials to marine environment. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidising substances; toxic materials; radioactive material; and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from exposure to hazardous materials. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column from contamination by oil, solvents and additives. • Impacts to human health and nutrition due to bio-accumulation of chemicals, affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) and associated revenues gained by tour operators through direct mortality from chemical incidents.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only. vii
				Avoid / minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines should be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning port infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Install permanent 'scrub-off' facilities to collect maintenance residues from operational areas.
				Minimise	Develop a surface water management plan to limit risk of chemicals entering the marine environment, e.g. contain and collect surface water from maintenance areas and test and treat before releasing to the marine environment.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their MSDS. Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.
Ancillary operations Helicopters for transportation to and from drill rig.	Noise disturbance in the marine environment.	• Noise from helicopter operations can cause fleeing in terrestrial and marine mammals and birds[187].	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impact to aesthetic beauty related to the noise, light and frequency or timing of helicopter trips.	Minimise	Prohibit helicopters from circling or hovering over marine mammals or sites identified as sensitive for seabird colonies and local communities unless essential for safety purposes[188].
				Minimise	Routine helicopter routes should be designed to avoid flying over coastal seabird colonies and local communities, particularly during sensitive periods (e.g. nesting periods, peak tourism season or periods of cultural festivities)[188].

vii Overboard disposal of all types of chemical waste from vessels is prohibited under MARPOL Annex II and III.

4.7. Field development

Field development is the process of turning an oil and gas exploration site into a sanctioned project. It involves identifying, developing and installing all the components required to develop and operate the oil and gas field. Production pads of different size and location will typically contain a number of vertical wells and associated underground lateral boreholes on a site. At this stage, associated equipment, such as pipelines and gas processing facilities, will be constructed. Once drilling has been completed, surface activity will diminish significantly as wells start to produce oil or gas.

Credit: FFI

All impacts described in the exploration drilling section are directly applicable for field development operations. The long-term implications of field development are typically the permanency of the site and the intense construction period. The level of construction activity is obviously proportional to the number of wells being drilled. Larger reservoirs that require a greater number of wells will be occupied for longer, and require more support services such as workforce accommodation, water supply, waste management, and other services.

The unique procedures associated with field development, as opposed to seismic or drilling activities, are the construction of the oil and gas facilities and laying of the subsea infrastructure. Typical subsea infrastructure includes production trees (well heads, production control system and manifolds), in-field flowlines and export pipelines (Figure 11).

Figure 11. Schematic of subsea infrastructure.

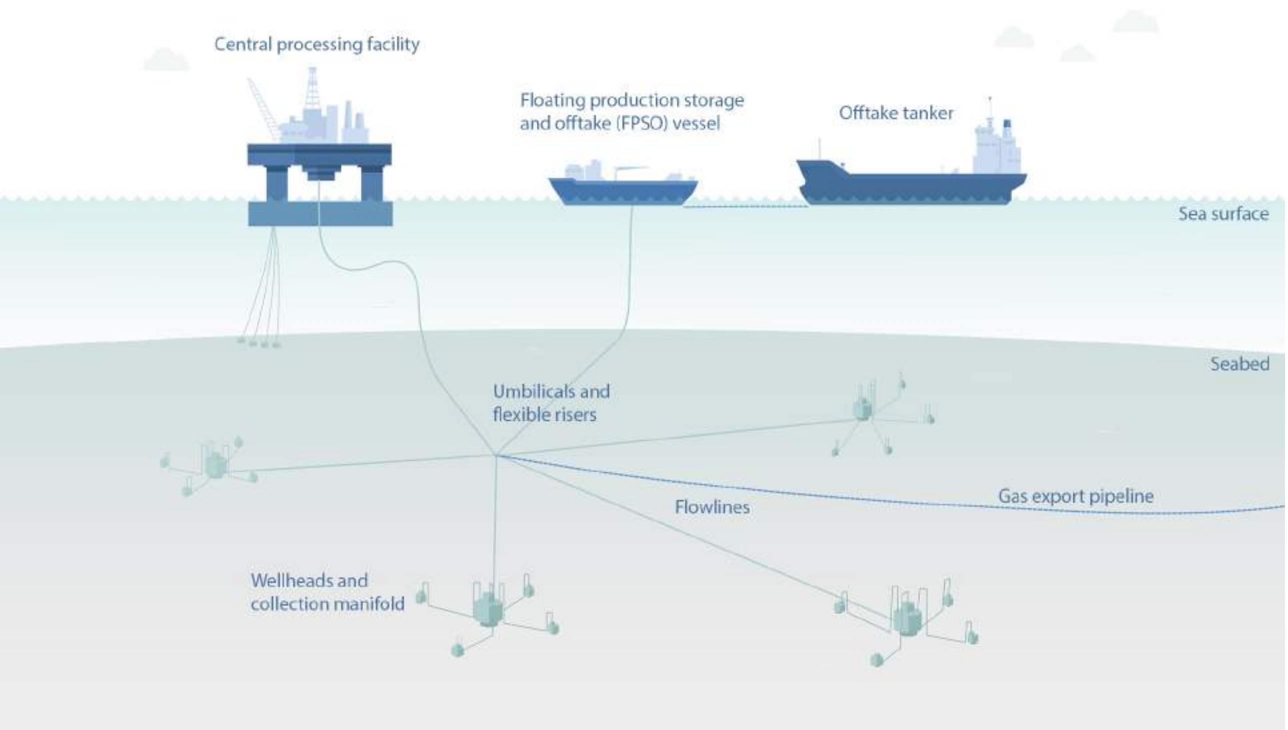


Table 5: Impacts associated with field development on marine biodiversity and ecosystem services, and recommended activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping In support of field development.	See 'Shipping' table for potential impacts and mitigations relating to shipping.				
Drilling In support of field development.	See 'Exploration Drilling' table for potential impacts and mitigations relating to drilling.				
Offshore field development Physical disturbance and presence of permanent subsea. Infrastructure (risers, flowlines, umbilicals, Xmas trees).	Loss or modification to benthic habitat. Increased suspended sediment and sedimentation.	• Damage or disturbance to sensitive benthic communities (e.g. deep water corals). • Creation of artificial habitat and modification of existing habitat, e.g. habitat for attachment organisms will be created, species will vary depending on depth. • Structure will be created in the pelagic environment, having a fish aggregation device (FAD) effect. • Possible local interference with migrating species. • May disrupt migration patterns or modify critical rearing areas of some organisms (e.g. crustaceans). • May lead to increased light or heat in the marine environment. • May cause discharge of operational chemicals, such as hydraulic oil.	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Loss of access to fishing grounds that are important to local fishing communities, and potentially increasing competition for fishing in surrounding waters. • Damage/ disturbance to seaweed/kelp forests impacting regulating and maintenance services of atmospheric composition and climate regulation (e.g. provision of oxygen, absorption of CO_2). • Damage or disturbance to benthic communities impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering).	Avoid / minimise	At site selection and design stage avoid, and then minimise, the placement of operational structures, pipelines and associated infrastructure in sensitive marine habitat. Site selection and design must be informed by benthic habitat surveys undertaken to identify sensitive habitats and biota that should be prioritised for avoidance. Studies should include regulating ecosystem services such as erosion and sediment control. Use information to guide site selection.
				Avoid	Determine what species are likely to be present in an area before commencing construction. Undertake development activities outside of sensitive lifecycle periods for relevant species, such as migration, breeding, calving and pupping (temporal avoidance). i
				Avoid	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.
				Minimise	Ensure a qualified Marine Mammal Observer (MMO) is on board in high risk habitats. To prevent a startle response from marine fauna undertake observations prior to commencement of work. If species are observed within a site specific exclusion zone, delay commencement until individuals clear the area. Only commence surveys during daylight hours when visual mitigation is possible.
Pipe laying Activities may include the laying of the pipeline, ancillary drilling, positioning anchors and cables	Potential to disturb the seabed and may physically damage infauna (i.e. the animals living in the sediments of the ocean floor or estuary bed).	• Burrowing infauna species may suffer mortality and benthic habitats can be directly disturbed from pipe laying. • Typically, pipelines will self-bury over time. Pipelines that do not become self-buried may create a local artificial hard substratum for colonisation by marine species (invertebrates and seaweed). • Pipelines are considered unlikely to create a barrier to the movement of seabed species[175].	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Loss of access to fishing grounds that are important to local fishing communities. • Damage to fishing gear from seabed infrastructure. • Damage or disturbance to benthic communities impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Impacts on physico-chemical conditions of the water column from increased turbidity.	Avoid	Spatially avoid at site selection design stage the placement of pipelines and associated infrastructure in sensitive marine habitat. Informed by an analysis of the oceanography of the pipeline route.
				Avoid	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Locate subsea infrastructure, in order to limit seabed preparation, trenching and secondary stabilisation requirements whilst ensuring pipeline integrity.
				Minimise	Reduce physical footprint where feasible (e.g. combine dual pipelines in one trench).

i Case Study: New pipeline, Russia (Sakhalin Energy Investment Company). Construction was timed to temporally avoid breeding/nesting periods, key migratory times, and feeding months for key species[14].

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Construction vessels Physical presence of mobile vessels and equipment during field development.	Vessels moving to/from the construction site have the potential to collide with marine fauna and block feeding areas and migration pathways; restricted areas for shipping prevent access to unauthorised vessels.	• Direct injury or mortality of marine fauna (e.g. migratory whales, turtles or migratory birds) as a result of collision with sea vessel. • Disturbance to migration, feeding and breeding patterns. • Behavioural changes or displacement of marine fauna such as marine turtles, whales and migratory wader birds.	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to the frequency or timing of shipping. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to movement of vessels with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Restricted access to traditional fishing grounds by local communities, reducing ability of subsistence fishers to catch fish and potentially increasing competition between fishers in surrounding waters.	Avoid	Monitor for presence and movements of large cetaceans, sirenia, and turtles (using observers on ships - Marine Mammal Observers (MMO) - and/or acoustic monitoring devices) so that collisions with vessels can be avoided. This mitigation action will only be effective for vessels capable of rapid manoeuvres (e.g. vessels of a few thousand GT or less)[88,89,90]. ii
				Avoid	Undertake activities outside of sensitive lifecycle periods for relevant species such as breeding or calving season.
				Minimise	Apply species-specific management actions to minimise adverse interactions. Interactions between vessels and marine fauna can be minimised through the implementation of speed limits and exclusion zones for construction vessels[131,132,133].
				Minimise	The enforcement of boat speed limits especially in shallow water depths will reduce the risk of fatalities and injury to marine fauna such as dugongs and turtles due to boat collisions. iii
				Minimise	Install boat speed signs and educational signs explaining the importance of adhering to boat speed limits.
Construction workforce Influx of construction workers in previously remote marine environment.	Recreational and / or illegal fishing leading to impact on marine resources.	• Increased pressure on recreational fish species and disturbance to inshore marine habitat and fauna.	• Increased pressure on fish species that are important to local fishing communities.	Avoid	Locate staff accommodation facilities away from sensitive marine facilities and transport staff to site[134].
				Minimise	Design and implement a bush meat action plan for aquatic bushmeat which includes all products sourced from wild aquatic megafauna. Measures must be context specific but might include the restriction of domestic pets that may prey on native species such as migratory birds or turtles, the employment of beach patrols/eco guards and raising awareness that the harvest of certain marine species is illegal.
				Minimise	Prohibit fishing and hunting on port lease holding, infrastructure and all operational vessels. Prohibit and enforce for employees and contractors the harvest or purchase of marine turtle products and other illegal activities. This should be communicated in a site induction and included in the disciplinary policy.
				Minimise	Restrict access to sensitive marine areas for all employees and the general public in those areas that are directly under company control[134].
				Minimise	Apply restrictions and enforced speed limits for recreational vessels especially in shallow water.
				Minimise	Raise awareness of all construction staff and contractors of environmental sensitivity and legal protection of local environment.
Chemicals associated with pipeline maintenance e.g. chemicals for preventing corrosion.	Protective coating to prevent external corrosion of pipeline may be released into the marine environment.	• Localised mortality of marine invertebrate species.	• Impacts to collection fisheries reliant upon shellfish and crustaceans. • Impacts to human health and nutrition due to health of fish caught and consumed.	Minimise	Best practices for pipeline corrosion protection should be implemented. May include sacrificial anodes, mastic coatings, etc.[189,190,191]

ii Monitoring is critical in areas of concentrations of sirenia (dugongs, manatees) and marine turtles
iii A speed limit of 4 knots per hour was placed on vessels in the Port of Mackay, Australia. Speeds were restricted to 6 knots in water depths of 2.5 m of less in other ports in Northern Australia.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Noise Underwater noise caused by subsea field development.	Avoidance of project area by marine fauna due to pile driving and construction activities. Underwater noise has the potential to displace marine megafauna from critical habitat and interrupt critical behaviours.	• Impacts of noise on marine mammals may be behavioural or physiological. • Behavioural impacts for marine mammals include changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant relationships, masking of biologically important sounds and avoidance of the noise sources[104]. • Physiological effects of underwater noise may include a reduction in animal hearing sensitivity or secondary effects associated with other systems including the vestibular system, reproductive system, nervous system and liver[104].	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through presence of noise and vibration. Altered behaviour of species of economic (e.g. commercial fish)or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Potential impacts on regulating services through through underwater noise affecting sediment-dwelling invertebrates which are important for nutrient cycling[192].	Avoid	Determine what species are likely to be present in an area before commencing field development. Undertake activities outside of sensitive lifecycle periods for relevant species, such as migration, breeding, calving and pupping.
				Minimise	Qualified Marine Mammal Observer (MMO) to be on board in high risk habitats. To prevent a startle response from marine fauna, undertake observations around piling operations prior to commencement of work. If species are observed within a site specific exclusion zone delay commencement until individuals clear the area. Only commence surveys during daylight hours when visual mitigation is possible. iv
				Minimise	Use soft start procedures for piling operations and dredging whereby the source level is increased gradually before use at full power. The expectation is that nearby animals respond by avoiding the sound source[141].
				Minimise	Use suction pile installation for piling activities (quieter) if possible[109].
				Minimise	Use sonar equipped with transducer operating frequency above 200kHz to minimise interference with marine mammals[142].
				Minimise	Use hydrophones to monitor underwater noises from relevant sources. Implement noise reduction measures (non-essential equipment shut down) when cumulative noise load exceeds 120dB@ 250m from vessel (120dB is the threshold at which Mysticeti whales are thought to avoid feeding and breeding activities. US Federal Register 70 FR 1871, 71 FR 3260, and 73 FR 41318)[108].
Lighting Artificial lighting used during field development.	Artificial lighting, used to illuminate infrastructure, spills into adjacent sensitive habitats.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight and condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • Fish may be attracted to light source, with larger aggregations increasing predation rates around sea vessels, resulting in loss of species abundance. • Artificial lighting can result in avoidance of nesting beaches by marine turtles and can impact on the ability of hatchlings to orientate after leaving the nest[127,194]. • Artificial lighting may disrupt and disorient sea birds. For example petrel fledglings are known to be attracted to light sources and are subsequently grounded leaving them vulnerable to other threats[129]. v	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to continuous light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to light disturbance (with species attracted to the lights and then potentially bio-accumulating the toxins released from the port as well as reducing abundance of fish in surrounding areas) with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Visual and aesthetic impact to seascape.	Minimise	Keep artificial lights to the minimum required to meet navigation and operational safety requirements[112].
				Minimise	Filter and/or shield lights in order to decrease light intensity for example use hoods and covers to reduce the amount of light spilling[130].
				Minimise	Redirect lighting away from sensitive habitats such as nesting beaches and wetlands adjacent to the port site.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing the attraction by migratory birds and turtles[113]. For turtles - use light sources that are 'turtles friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium- vapour lighting is the purest yellow light source and recommended due to being the best commercially available solution[114].
				Minimise	Make personnel working on site aware of threatened and migratory species that may be grounded as a result of artificial lighting.

iv For example, Gladstone LNG project established a 350 m exclusion zone around piling work for dugong, whale shark, humpback whale or dolphin. To prevent a startle response, at the start of impact piling in deeper water (>3m); observations were made of an area approximately 350 m radius around the pile before commencement. If such species were observed within the area then commencement of impact piling was delayed until they cleared the area[193].
v The extent of impact will depend on the extent to which sensitive species become accustomed to noise and illumination at night. For example migratory birds have been known to forage and roost in close proximity to existing port developments.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Dredging Removal of sediment for field development.	Removal of benthic habitat; increased turbidity and local sedimentation.	• Destruction of sensitive marine habitats, e.g. seagrass. Destruction of habitat for benthic and burrowing species. • Reduced productivity or mortality due to light limitation. • High rates of sedimentation can result in burial of sessile flora and fauna. • High levels of suspended sediment can interfere with locating prey, and alter the movement patterns of larval fish. • Possible increase in coral diseases[136] through stress from elevated turbidity leading to reduced fitness.	• Reduced productivity of fisheries (especially in shallow water); Turbidity can cause abrasion of fish gills, interfere with migration, and increase predation on juvenile fishes. • Destruction of nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Damage or disturbance to sensitive benthic habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Interference with and exclusion of traditional, recreational and commercial fishers, and tourism operators.	Avoid	At site selection design stage, avoid the placement of shipping lanes and dredging zones in sensitive marine habitat including areas identified as important for fishing (e.g. areas that support local fishers or are key to recruitment of commercial species) and cultural importance. Ensure site selection is informed by an analysis of the oceanography of the dredging zones, and plume model studies[95].
				Avoid	Develop plans for exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Establish a dredge management plan that outlines measures to minimise impacts and suitable management responses when trigger values for marine water quality are exceeded, i.e. findings of the water quality monitoring program should be used to determine water quality parameters for the Dredge Management Plan and trigger levels for each parameter above which work practices will need to be reviewed or suspended.
				Minimise	Investigate the use of dredging equipment and techniques that will limit the impact on the relevant habitats or species. For example the use of Cutter Suction Dredger type dredger may reduce the mobilisation of fine sediment in an area in close proximity to marine communities that are sensitive to increases in turbidity.
				Minimise	Use a silt curtain/screen to control suspended solids resulting from dredging operations. A silt curtain is an 'impermeable device for control of suspended solids and turbidity in the water' column such as a floating vertical barrier. A silt screen is a flow-through filtering device created with permeable geosynthetic fabrics which filter water and reduce water pressure on the device[137,138].
				Minimise	Reduce footprint, duration and volume of dredging to the minimum required. For example locating jetty structures in deeper water to reduce the need to undertake capital and maintenance dredging of shipping channels.
				Minimise	Consider timing of operation to avoid or minimise environmental effects. Seek guidance at the earliest stages from environmental agencies, on most appropriate times to undertake dredging to avoid or minimise disturbance to marine features[139].
				Minimise	Manage sediment loading and deposition processes to minimise suspended sediment. Alter the time of year of dredging and disposal to reduce impacts on sensitive benthic and pelagic communities and / or critical life phases, e.g. coral spawning, whale calving. vi
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.

vi Use specialised dredging equipment e.g., turtle excluding devices

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Dredging Disposal of dredge spoil.	Displacement of benthic habitat and increased suspended sediment in water column.	• Destruction of valuable marine habitats, e.g. seagrass or coral. • Destruction of habitat for benthic and burrowing species. • Increases in suspended sediment lead to reduced primary production through reduced light levels. • Increased sediment deposition on sensitive habitats such as coral reefs. • Burial of sessile organisms unable to cope with sediment deposition.	• Reduced productivity of fisheries (especially in shallow water); Turbidity can cause abrasion of fish gills, interfere with migration, and increase predation on juvenile fishes. • Destruction of nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Damage or disturbance to sensitive benthic habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering).	Avoid	At site selection design stage, avoid the placement of spoil deposition in zones of sensitive marine habitat and areas identified as important for local fisheries or cultural significance. Esnure site selection is informed by an analysis of the oceanography of the spoil deposition zones and plume model studies.
				Avoid/ minimise	Undertake options analysis for the location of spoil disposal. Consider the option of placing dredge onshore when port infrastructure is located in close proximity to marine protected areas. Consider alternative uses for dredge material including: land reclamation, beach nourishment, offshore berms, capping material, agriculture, environmental habitat restoration - keeping it within the local sedimentary system[139]. vii
				Minimise	Minimise the extent of the dredge spoil disposal area.
				Minimise	Outline measures to identify and address the re-suspension of marine sediments containing harmful compounds such as tributyltin (TBT). Analysis of benthic sediments should be undertaken prior to dredging activities and measures established for safe disposal /containment[139].
Hazardous materials Planned or accidental release of toxic substances during field development.	Discharge of hazardous materials 'hazmats' to marine environment. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidising substances; toxic materials; radioactive material; and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from hazardous substances. • Impacts on regulating and maintenance services through impacts on the phyico-chemical conditions of the water column from contaminants. • Impacts to human health and nutrition due to chemicals bio accumulating and affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through direct mortality from chemical incidents or alteration of marine environment. • Potential to inundate waste assimilation services thereby reducing this function.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only. viii
				Avoid / minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines should be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Ensure contractors have experience of management of hazardous residual materials and containment of fluids and have the systems, processes and procedures in place to manage the risks[195].
				Minimise	Install permanent 'scrub-off' facilities to collect maintenance residues from operational areas.
				Minimise	Develop suitable removal methodology, ensure space is available to sort and segregate waste into skips[195], ensure suitable skips are available for all waste types, and suitable waste handling facilities for recycling or disposal have been identified.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their MSDS. Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.

vii Aerial exposure of certain soils can lead to the production of sulphuric acid and the release of toxic quantities of iron, aluminium and heavy metals[140].
viii Overboard disposal of all types of chemical waste from vessels is prohibited under MARPOL Annex II and III.

4.8. Production/operations

The production/operations phase commences following the completion of the field development phase and will typically last 10-30 years depending on the capacity of the reservoir. The drilling impacts and consequences associated with operation and production are similar to exploration drilling, however, projects must consider the long-term permanent presence of the structures and ongoing activities on a site specific basis. Furthermore, in production, drilling is often extensive within a small area (fields may consist of tens of wells, some of which may be closely spaced). Production is gradually increased to a peak before it starts to decline. When this occurs the operator may inject water or gas into the reservoir or drill new wells into nearby reservoirs and connect to the existing platform[196].

Exactly how a field will be developed will depend on the type (oil or gas), the location and the social and environmental constraints. Infrastructure may include the following:

- Onshore processing facilities such as petroleum and LNG terminals
- Subsea pipelines
- Offshore processing facilities such as oil platforms (Figure 12)
- Floating Storage and Regasification Units (FSRU)

Figure 12. Operations Phase for an oil platform – potential discharges and emissions

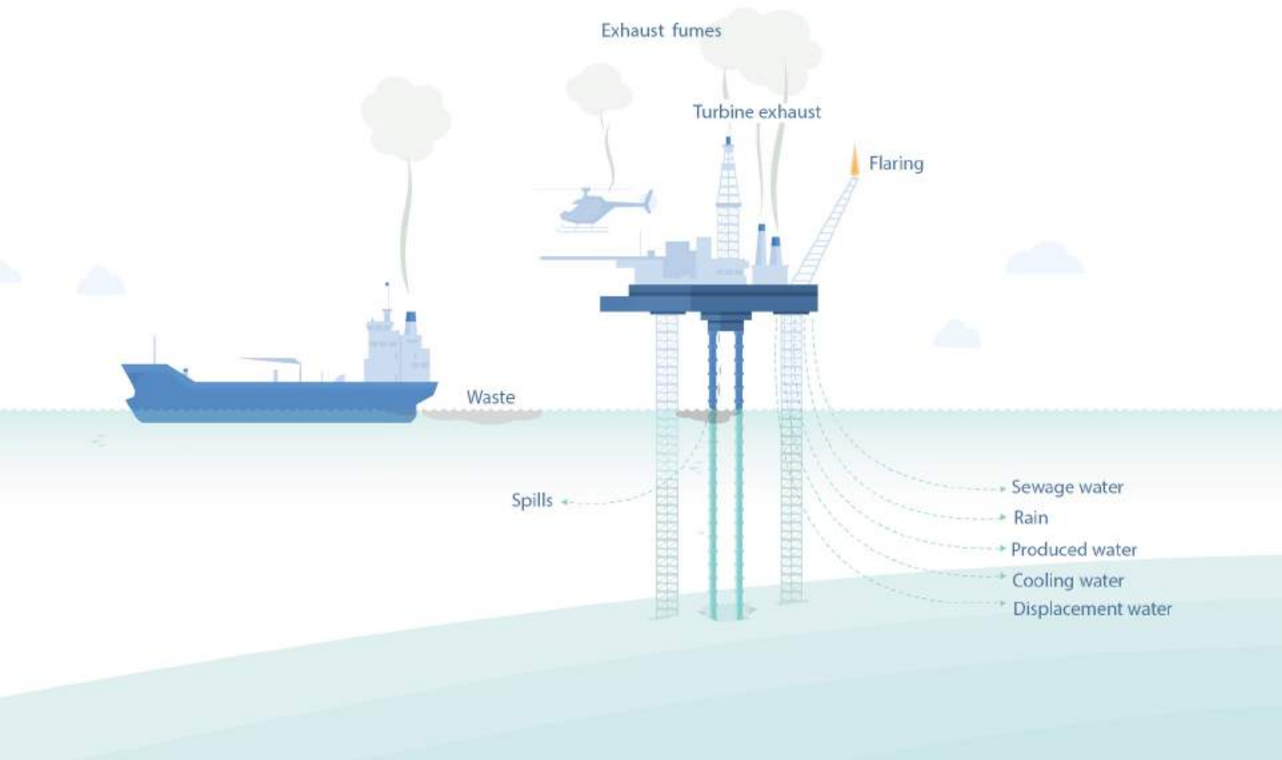


Table 6: Impacts associated with the operational phase on marine biodiversity and ecosystem services, and recommended activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping In support of construction and operation of a port.	See 'Shipping' table for potential impacts and mitigations relating to shipping.				
Terminal Infrastructure Construction of petroleum and LNG terminals	See 'Port infrastructure (construction and operation)' table for potential impacts and mitigations relating to the construction of petroleum and LNG terminals.				
Construction workforce Influx of construction workers in previously remote marine environment.	Employees and contractors undertaking recreational fishing or hunting of marine mammals.	• Increased pressure on recreational fish species and disturbance to marine habitat and fauna.	• Increased pressure on fish species that are important to local fishing communities.	Avoid	Locate all staff accommodation facilities away from sensitive marine facilities and transport staff to site (where possible)[134].
				Minimise	Design and implement a bush meat action plan for aquatic bushmeat which includes all products sourced from wild aquatic megafauna. Measures must be context specific but might include the restriction of domestic pets that may prey on native species such as migratory birds or turtles, the employment of beach patrols/eco guards and raising awareness that the harvest of certain marine species is illegal.
				Minimise	Prohibit fishing and hunting on all project facilities and for all staff and contractors. Prohibit employees and contractors from harvesting or purchasing protected species, e.g. marine turtle products. This should be communicated in a site induction and included in the disciplinary policy.
				Minimise	Restrict access to sensitive marine areas for all employees and contractors and the general public in those areas that are directly under company control[134].
				Minimise	Apply restrictions and enforce speed limits for recreational vessels, especially in shallow water.
				Minimise	Raise awareness among all construction staff and contractors on environmental sensitivity and legal protection of local environment.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
<u>LNG / Petroleum terminal - Lighting</u> Artificial lighting used during terminal operation.	Artificial lighting, used to illuminate terminal infrastructure, spills into adjacent sensitive habitats.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight and condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • Fish may be attracted to terminal's light source with larger aggregations increasing predation rates around sea vessels, resulting in loss of species abundance. • Artificial lighting can result in avoidance of nesting beaches by marine turtles and can impact on the ability of hatchlings to orientate after leaving the nest[127]. • Artificial lighting may disrupt and disorient sea birds. For example petrel fledglings are known to be attracted to light sources and are subsequently grounded leaving them vulnerable to other threats[129]. i	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to continuous light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to light disturbance (with species attracted to the lights and then bio-accumulating the toxins released from the port as well as reducing abundance of fish in surrounding areas) with implications for livelihoods and nutrition (e.g. fisheries, tourism) • Visual and aesthetic impact to seascape.	Minimise	Keep artificial lights to the minimum required to meet navigation and operational safety requirements[112].
				Minimise	Filter and/or shield lights in order to decrease light intensity for example use hoods and covers to reduce the amount of light spilling[130].
				Minimise	Direct lighting away from sensitive habitats such as nesting beaches and wetlands adjacent to the port site.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing the attraction by migratory birds and turtles[113]. For turtles - use light sources that are 'turtles friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium- vapour lighting is the purest yellow light source and recommended due to being the best commercially available solution[114].
				Minimise	Make personnel working on site aware of threatened and migratory species that may be grounded as a result of artificial lighting.
<u>Subsea infrastructure (risers, flow-lines, umbilicals, christmas tree)</u> presence in marine environment. ii	Loss or modification of benthic habitat; creation of pipes connecting bottom with surface.	• Some benthic infauna will be displaced. • Creation of artificial habitat and modification of existing habitat, e.g. habitat for attachment organisms will be created, species will vary depending on depth. • Structure will be created in the pelagic environment, having a fish aggregation device (FAD) effect.	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Loss of access to fishing grounds that are important to local fishing communities. • Structures cause altered behaviour of fish, leading to areas of abundance around the structures and reducing abundance of fish in surrounding area with possible impacts for commercial and local fishing. • Damage or disturbance to benthic habitat impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Damage/ disturbance to benthic habitat impacting regulating and maintenance services of atmospheric composition and climate regulation (e.g. provision of oxygen, absorption of CO_2).	Avoid / minimise	At site selection and design stage avoid, and then minimise, the placement of operational structures, pipe-lines and associated infrastructure in sensitive marine habitat. Site selection and design must be informed by benthic habitat surveys undertaken to identify sensitive habitats and biota that should be prioritised for avoidance. Studies should include regulating ES such as erosion and sediment control. Use information to guide site selection.
				Minimise	Use of best practices in construction materials and maintenance of facilities to minimise disturbance from noise, light, temperature, chemicals and vibration.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.

i The extent of impact will depend on the extent to which sensitive species become accustomed to noise and illumination at night. For example, migratory birds have been known to forage and roost in close proximity to existing port developments.
ii Flowlines: pipelines carrying reservoir fluid on the seabed from wells to risers; umbilicals: flexible cables carrying electrical and instrument wiring, hydraulic tubing and chemical tubing; christmas tree: the system of pipes, valves, gauges and related equipment located on the well at ground level which controls the flow of gas and other petroleum products produced from the well.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Floating Storage and Regasification Units Water uptake.	Uptake of seawater.	• Impingement and entrainment mortality of fish, ichthyoplankton and shellfish at the intake opening. Especially in spawning, rearing and feeding areas for important marine species. iii • Change in flow dynamics in estuarine areas.	• Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Mortality of fish impacts provisioning services. • Change in flow dynamics alters regulating services such as mediation of flows and waste.	Avoid	Undertake baseline studies to identify sensitive areas, e.g. spawning, rearing and feeding areas.
				Avoid	Position the facility to avoid sensate areas, e.g. spawning, rearing and feeding areas for important marine species.
				Minimise	Use best practice guidance (e.g. IFC EHS Guidelines for Thermal Power Plants (2008) and US EPA standards relating to water consumption and aquatic habitat alteration) to have a maximum through-screen design intake velocity is 0.5 ft/s or less and design intact screens to minimising impingement and entrainment mortality.
				Minimise	Limit quantities of water use to that which can be accommodated in the water body without significant impact on biota.
Floating Storage and Regasification Units Water discharge.	Discharges of water with different temperature of receiving waters. Discharges of concentration of free chlorine in the effluent of the vaporisation process.	• May cause thermal shock to local organisms with limited mobility (e.g. eggs and larvae). • Chemicals within discharge water (e.g. chlorine) may be locally toxic to sensitive organisms. • Heated wastewater can stress corals and disrupt the composition and health of reef communities. Corals are particularly sensitive to thermal stress: temperatures increases of just a few degrees for extended periods can cause corals to bleach and die[182,183].	• Release of warm water impacts the physico-chemical conditions of the water column potentially impacting regulating and provisioning services through disruption of breeding of commercially important species, e.g. fish and shellfish. • Release of warm water linked to suppressed recruitment in bryozoans and polychaetes[184]. • Thermal shock could reduce fitness of coral reefs, leading to adverse impacts to tourism.	Avoid	At site selection stage, locate outfall to avoid sensitive habitats.
				Minimise	Design discharge system to minimise thermal plume of discharged water.
				Minimise	Use modelling to predict how the thermal plume will disperse in the water column and use results to avoid fish spawning grounds.
				Minimise	Follow IFC guidelines (2008) for thermal discharge.
				Minimise	Follow IFC guidelines (2008) for discharge of free chlorine in the effluent of the vaporisation process in LNG plants (0.2 mg Cl_2/l). Monitoring and evaluation should be performed to ensure standards are achieved.
Natural gas Produced during the course of routine oil and gas production operations.	Discharges to air - flaring and venting.	• Possible attractant to birds (flaring) Injury and potential mortality of marine birds nesting on flare stacks. • Contribution to climate change. OGP estimates that flaring contributes 1% of global anthropogenic CO_2 emissions and flaring and venting combined contribute 4% of global methane emissions[197], with widespread associated impacts on BES worldwide.	• Impact on cultural services if bird collisions occur as birds are a source of cultural and national significance and can provide economic benefit through tourism. • Impact on regulatory services if migratory species collide with the flare as they link ecosystem processes and nutrient fluxes. • Impact on climate regulation services through the release of greenhouse gases into the atmosphere.	Avoid	Re-inject gas in to underground reservoirs.
				Avoid	Install nesting guards to prevent bird landings on flare stacks.
				Minimise	Sound alarm before igniting flare.
				Minimise	Schedule routine visual inspections for nesting species and relocated to suitable habitat if found.
				Minimise	Inject steam into the burner to reduce the heat, smoke and the luminosity of the flame.
				Minimise	Install combustion systems with high efficiency to ensure complete combustion, with the aim of reducing the emission of pollutants into the air.
				Minimise	Ensure regular maintenance of the flare stack.

iii Impingement occurs when the entrapped organism is held in contact with a barrier by water movement (generally some type of screen located within the intake structure). Entrainment: when an organism is drawn into an intake in the body of water which it occupies.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Generation of inorganic waste All operation/production facilities.	Pollution of marine environment by release of inorganic waste, e.g. plastic, lumber, metal, concrete, etc.	• Ingestion of plastic waste can cause individuals to die of starvation or malnutrition. • Diving birds can become entangled in plastic waste - can lead to infection, loss of limbs or death. • Plastic waste can leach toxic substances to sediments and water where it can be absorbed by small algae and animals and cause bioaccumulation in other animals feeding on them[115]. • Toxic plastics can be ingested directly by fish, exposing species further up the food chain to these pollutants - can lead to death from toxic poisoning[116]. • Hard materials will change the benthic habitat by displacement on infauna, but may provide substrate for marine organisms to colonise on soft seabeds. • Leaching of harmful compounds may occur.	• Impacts to provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality and disruption of food web caused by plastics. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through impact to aesthetic beauty from plastic waste and direct mortality to species important to tourism. • Impacts to human health and nutrition due to health of fish caught and consumed. • Impacts on regulating and maintenance services through impact on physico-chemical conditions of the water column due to turbidity.	Avoid	Do not dispose of plastic waste overboard; collect all plastic waste for onshore disposal by reputable waste management contractors only, and seek recycling options where available[117]. [iv]
				Minimise	Efforts should be made to eliminate, reduce, or recycle wastes at all times[117].
				Minimise	A management plan must be developed and implemented to minimise discharge of each type of solid waste. At a minimum, IFC EHS General Guidelines must be followed. The plan should consider upland disposal of solid wastes in approved sites.
				Minimise	Staff will be given induction to manage solid waste for recycling and disposal.
Generation of organic waste - all operation / production facilities.	Offshore facilities dispose of wastes (including kitchen waste, effluent, sewage and grey water) at sea.	• In near-coastal waters or estuaries with poor flushing, can result in reduced benthos biodiversity and abundance, changes in fish behaviour, stress and acute or latent mortality of marine species through lack of oxygen. • May introduce pathogens and cause turbidity that would affect local sensitive organisms with limited mobility (benthos and eggs). • Increase in biological oxygen demand and a reduction in habitat quality[119]. Can result in eutrophication (algal blooms).	• Impact to regulating service of waste assimilation through inundation of waste; impacts to human health from increased waste in environment. • Impact on provisioning services through impacts to changing behaviour of nektonic and other species attracted to nutrients from waste. • Impact to provisioning services by increasing health risks from consuming commercial species, such as filter feeding shellfish. • Impacts on regulating and maintenance services through impacts on the physico-chemical conditions of the water column from increased nutrient levels and suspended matter.	Avoid	Treat all sewage and grey water (to recognised standards) prior to discharge OR no disposal at sea - disposal at port by reputable waste management contractors only[120].
				Avoid	Collect and compact all domestic waste for onshore disposal. Ensure detailed documentation and manifesting. Ensure that onshore receiving and disposal companies meet local and international requirements.
				Minimise	Use waste segregation at source for different types (organic, inorganic industrial wastes, etc.).
				Minimise	No disposal of untreated sewage or grey-water within 12 nautical miles of land[120].
				Minimise	Treat all sewage and grey water according to MARPOL requirements prior to discharge OR no disposal at sea - disposal at port by reputable waste management contractors only.
				Minimise	Store used cooking oils in suitably contained areas. Limit quantities stored to a minimum. Ensure detailed control documentation and manifesting for disposal.

iv Overboard disposal of all types of solid waste from vessels is prohibited under MARPOL Annex V

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Generation of hazardous waste – all operation/production facilities.	Discharge of hazardous materials to marine environment. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidising substances; toxic materials; radioactive material; and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from hazardous substances. • Impacts on regulating and maintenance services through impacts on the phyico-chemical conditions of the water column from contaminants. • Impacts to human health and nutrition due to chemicals bio accumulating and affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through direct mortality from chemical incidents or alteration of marine environment. • Potential to inundate waste assimilation services thereby reducing this function.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only. v
				Avoid / minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines must be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning port infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Install permanent 'scrub-off' facilities to collect maintenance residues from operational areas.
				Minimise	Develop a surface water management plan to limit risk of chemicals entering the marine environment, e.g. contain and collect surface water from maintenance areas and test and treat before releasing to the marine environment.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their MSDS. Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.

v Overboard disposal of all types of chemical waste from vessels is prohibited under MARPOL[20] Annex II and III.

4.9. Decommissioning

Decommissioning and closure is a key phase in any oil and gas project's life in which ongoing social and environmental risks that endure beyond the production phase of the project must be managed. An increasing number of producing oil and gas fields will near depletion or the economic limits of extractability in the coming years. Thus, closure activities are expected to increase globally[198].

Credit: Allseas

All projects must consider decommissioning or a closure/abandonment plan as part of the environmental management of the project. Such decommissioning plans should be established during the early stages of the project. Closure of operations and abandonment includes all the activities related to the closure of a main facility and its installations at the end of the estimated useful life and the activities related to the proper abandonment of the installations and the rehabilitation of the site. When addressed during the early stages of the project life cycle (e.g. design phase), costs associated with decommissioning can be significantly reduced (for example, siting of specific components, avoidance of sensitive areas, establishment of financial guarantees, etc.)[198].

The closure of the operation should be a programmed action that:

- ensures compliance with the legislation in the date programmed for the closure;
- in the absence of specific legislation, specifies the project proponent will confirm to the proper authorities that all the actions have been taken to protect human life and the surrounding environment; and
- requires the operating company to delimit its environmental responsibilities "before" and "after" the closure of the Project.

The general approach adopted upon closure of the operations of a project are outlined below:

- The project proponent should estimate a minimum useful life of the facility in years (which could be extended under optimum maintenance conditions).
- The installations to be closed should be assessed and handled in a context-specific manner.
- Installations to that are to be abandoned will be disconnected from all sources and supplies of gas, oil, and water. This includes, for example, pipelines, metering stations, control lines, and other installations.
- All pipelines will have contents (e.g. petroleum or LNG) safely removed and properly disposed of before the pipelines are sealed.
- Surface equipment shall be removed and taken away, with the possible exception of buildings. It is expected that these may remain in place until they are sold or demolished.
- The area and facilities may be converted into another use (e.g. a recreation or industrial park), assuming all health, safety and environmental criteria have been met.

For decommissioning, the environmental requirements and guidelines for marine BES established for the construction stage will apply. Specifically, the following concerns created by the dismantling work must be managed in an environmentally sensitive manner, namely:

- Generation of solid waste;
- Generation of liquid effluents;
- Gaseous emissions;
- Particulate matter emissions;
- Generation of noise and vibrations; and
- Physical presence.

Once the dismantling tasks are completed the environmental conditions in the occupied area will be re-established, by performing at least the following:

- As far as possible the areas affected by the physical presence of the structures will be restored returning them to their initial condition and function. This includes the reconstitution of the surface affected and the seascape of the area.
- The areas affected during the decommissioning will be restored as much as possible, returning them as close as possible to their initial condition. This includes the reconstitution of the beach or benthic surface affected in order to not alter the natural water flow.
- In the event that any man-made feature is considered an improvement for the environment, it may be left with the agreement with the relevant authorities[iii].

iii Leaving structures in place is common in the Gulf of Mexico through the Rigs-to-Reefs programme (as they have an assumed benefit). In the OSPAR area (some of Europe) the presumption is opposite (i.e. it is more beneficial for them to be removed).

Credit: Pippa Howard

Box 14: A case study of a UK decommissioning project

At present in the UK alone some 475 oil and gas installations, 10,000 kilometres of pipelines, 15 onshore terminals and 5,000 wells will eventually have to be decommissioned. Of these, over 50 fields will either be approaching or undertaking decommissioning by 2018[199]. The Oslo and Paris (OSPAR) Convention, which provides the legislative framework for protecting and conserving the north-east Atlantic, has prohibited the dumping, and leaving wholly or partly in place, of disused offshore installations (OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations). However, it is possible to gain permission to leave some large concrete and steel structures in place or partially in place (derogation cases). The first two installations in the UK to receive BEIS approval for decommissioning programmes that leave the structures in place are NW Hutton, operated by BP, and Frigg MCP01, operated by Total. Several other installations and pipelines have been identified to be likely to apply for OSPAR derogation owing to their size and difficulty in removing safely. In total in the UK there is the potential for up to nine concrete platforms, 31 large steel platforms and 5,300km of large diameter trunk pipelines to be considered for leaving in place[200].

The Guidance Notes for Industry on the Decommissioning of Offshore Installations and Pipelines under the Petroleum Act 1998 (DGN: DECC, 2011) state that Decommissioning Programmes will need to be supported by an EIA. The EIA will have to include environmental baseline surveys, if the area has not been surveyed in the last five years, the precise nature of which depends on the individual conditions. The presence of the coldwater coral, *Lophelia pertusa*, or reef forming worm, *Sabellaria*, should be established, and if present, the potential impact of the operations on these species should be assessed in the EIA. Furthermore, a post-decommissioning environmental seabed sampling survey should be undertaken, in particular to monitor levels of hydrocarbons, heavy metals and other contaminants in sediment and biota. This should be followed in most cases by a second survey undertaken after the post-decommissioning sampling. In the case of the Frigg field, three environmental surveys were done: a pre-removal survey in May 2003, a during-removal survey in May 2006 and a post-removal survey in May 2010. These surveys included both chemical and biological analyses of the sediments surrounding the decommissioned structures.

In addition to the environmental monitoring, the condition of the remains will have to be monitored at appropriate intervals by the owners of the structures. The monitoring regime will be agreed with the appropriate authority (currently the Department for Business, Energy and Industrial Strategy) and the details of the monitoring regime should be specified in the decommissioning programme. However, the existing programmes only state that the future monitoring scheme will be determined in conjunction with the appropriate authority[201].

Table7: Impacts associated with decommissioning on marine biodiversity and ecosystem services, and recommended activities to avoid and minimise impacts

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Shipping – in support of decommissioning.	See 'Shipping' table for potential impacts and mitigations relating to shipping.				
Planning Lack of decommissioning plans in line with legislation.	Non-compliance; risk to marine BES from a range of decommissioning related impacts (detailed below).	• Wide range of possible impacts, from displacement to injury to death of marine organisms (see below).	• Impacts on fishing, including risk of fouling gear on improperly decommissioned facilities, changes to physico-chemical conditions, and injury or death of economically important species (see below).	Avoid	Develop detailed decommissioning plan, in line with regional conventions and national policy and legislation (e.g. OSPAR for the North Sea). i
Pipelines Decommissioning of pipelines and protective infrastruture	Disturbance of benthic environment.	• Displacement of benthic species Injury or death of benthic species.	• Impacts on physico-chemical conditions of the water column from increased turbidity. • Impacts on provisioning services through impacts to nektonic and other species. • Impacts on provisioning services due to auditory, visual and vibration disturbance to fish and other species, altering behaviour. • Damage or disturbance to benthic communities impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering). • Loss of access to fishing grounds that are important to local fishing communities.	Avoid / minimise	Assess different options for the decommissioning of pipelines, which can include backfill in-situ, leave in-situ or total removal. Complete removal is generally not required. ii
				Minimise	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
Hazardous waste Removal and disposal.	Discharge of hazardous materials 'hazmats' to marine environment. Hazmats can be classified according to the hazard as explosives; compressed gases, including toxic or flammable gases; flammable liquids; flammable solids; oxidising substances; toxic materials; radioactive material; and corrosive substances.	• A wide variety of stresses and potential mortality of marine life will occur, depending on the material and amounts discharged.	• Impacts for provisioning services through reduction in the availability of species important to commercial or subsistence fisheries due to direct mortality from hazardous substances. • Impacts on regulating and maintenance services through impacts on the phyico-chemical conditions of the water column from contaminants. • Impacts to human health and nutrition due to chemicals bio accumulating and affecting the health of fish caught and consumed. • Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through direct mortality from chemical incidents or alteration of marine environment. • Potential to inundate waste assimilation services thereby reducing this function.	Avoid	Do not dispose of waste chemicals overboard; disposal at port by reputable/licenced waste management contractors only. iii
				Avoid / minimise	A hazardous materials management plan must be developed and implemented to minimise impacts of each type of hazardous waste. At a minimum, IFC EHS General Guidelines must be followed.
				Minimise	Use environmentally sensitive alternatives to harmful chemical agents when cleaning infrastructure. For example, the use of high pressure cleaning techniques.
				Minimise	Ensure contractors have experience of management of hazardous residual materials and containment of fluids and have the systems, processes and procedures in place to manage the risks[195].
				Minimise	Develop suitable removal methodology, ensure space is available to sort and segregate waste into skips[195], ensure suitable skips are available for all waste types, and suitable waste handling facilities for recycling or disposal have been identified.
				Minimise	Store all hazardous materials in suitably contained areas, in accordance with their MSDS. Limit quantities stored to a minimum level required for operational purposes. Ensure detailed control documentation and manifesting for disposal.

i Decommissioning is commonly governed by law. For e.g., the UK's international obligations on the decommissioning of offshore installations have their origins in the United Nations Convention on the Law of the Sea of 1982. In 1992 the Convention on the Protection of the Marine Environment of the North East Atlantic ("the OSPAR Convention"), was agreed. In July 1998 a new regime for the decommissioning of disused offshore installations was established under OSPAR.
ii Requirements for pipeline removal vary. In the North Atlantic, the OSPAR Convention have not made any recommendation for pipelines, and there is currently no obligation to remove them under international law[202]. However, many national laws do; for e.g. under Uk legislation (Petroleum Act 1998) pipeline removal is considered on a case-by-case basis[203].
iii Overboard disposal of all types of chemical waste from vessels is prohibited under MARPOL Annex II and III.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Decommissioning of subsea facilities Risers, flowlines, umbilicals, Xmas trees.	Decommissioning of subsea facilities, some of which may be embedded in the sea floor, can create heavy disturbance to the seafloor.	• Displacement of benthic species. • Injury or death of sessile species unable to move away from areas where subsea facilities are removed. • Smothering of organisms, resulting in reduced ability to feed, and potential ill health and mortality.	• Impacts on physico-chemical conditions of the water column from increased turbidity. • Damage or disturbance to nursery, feeding and breeding grounds for fish and shellfish that are important to commercial and local fishing communities for revenue and nutrition. • Loss of access to fishing grounds that are important to local fishing communities, and potentially increasing competition for fishing in surrounding waters. • Damage/ disturbance to seaweed/kelp forests impacting regulating and maintenance services of atmospheric composition and climate regulation (e.g. provision of oxygen, absorption of CO_2). • Damage or disturbance to benthic communities impacting regulating and maintenance services of mediation of mass and liquid flows (e.g. through erosion control, sediment storage and reducing wave or storm intensity) and mediation of waste (e.g. sedimentation filtering).	Avoid	Leave clean steel and concrete structures in-situ. iv
				Avoid	Determine what species are likely to be present in an area before commencing decommissioning activities. Undertake development activities outside of sensitive lifecycle periods for relevant species, such as migration, breeding, calving and pupping (temporal avoidance).
				Minimise	Develop exclusion zones in consultation with key stakeholders including local fisher communities; raise awareness of exclusion zones with all stakeholders.
				Minimise	Meet with fishing communities to assess potential impacts for fisheries and develop plans for mitigation that are appropriate to the local context.
				Minimise	Assess different options for the decommissioning of subsea structures, considering that total removal could create more disturbance to the marine environment than partial decommissioning in-situ.
Explosives Used for wellhead or platform decommissioning (typically used to sever pilings prior to their removal by crane).	Heavy disturbance of the marine environment.	• Direct injury and mortality of marine species, particularly benthic species, but also fish and marine mammals and reptiles[204,205]. • Destruction of benthic environment.	• Impacts on physico-chemical conditions of the water column from increased turbidity. • Impacts on provisioning services through impacts to nektonic and other species. • Impacts on provisioning services due to auditory disturbance to fish and other species, altering behaviour.	Avoid	Determine what marine mammal species are likely to be present in the detonation area and assess if there are any seasonal considerations that need to be taken in to account, e.g. migration, breeding and calving[206]. Avoid sensitive periods.
				Minimise	Determine the distance at which the explosive detonations could cause physical injury to marine mammals and establish suitable mitigation zone. Default mitigation zone for marine mammal observation mitigation should be 1km, measured from the explosive source, 360 degrees circular coverage[206]. This radius can be increased/decreased if there is supporting evidence to do so following consultation with the appropriate nature conservation organisation.
				Minimise	Only commence explosive detonations during the hours of daylight and good visibility (observers should be able to monitor the full extent of the mitigation zone). If marine mammals are observed, delay detonation (dedicated and trained marine mammal observers should carry out observations). Delay should last for at least 20 minutes of a marine mammal leaving the mitigation zone.
				Minimise	In darkness or low visibility, use a Passive Acoustic Monitoring (PAM) to detect marine species likely to be present in the area. PAM operatives should assess any acoustic detections and determine if there are likely to be marine mammals within 500m of the source. If present, the operation should be delayed[206].
				Minimise	Use Active Acoustic Monitoring (AAM) to supplement visual observations and PAM as mitigation measures. AAM can detect animal presence in all conditions regardless of whether animals are vocalising.
				Minimise	Conduct pre-detonation searches for marine mammals at least 1 hour before any type of detonation. Visual and acoustic monitoring should be conducted by a trained marine mammal observer in the mitigation zone and should continue until the observer advises that the mitigation zone is clear.
				Minimise	Accurately determine the amount of explosive required for the operation, so that the amount is proportionate to the activity and not excessive[206].
				Minimise	Plan the sequence of multiple explosive charges so that, where possible, smaller charges are detonated first to maximise a 'soft-start' effect.

iv Remaining subsea structures can benefit the local ecology by providing an artificial habitat to marine species.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Lighting Artificial lighting used during decommissioning.	Artificial lighting, used to illuminate infrastructure, spills into adjacent sensitive habitats.	• Marine species can be attracted to light source and become disorientated[111]. • Marine mammals can stop feeding, resting, travelling and/or socialising, with possible long term effects of repeated disturbance including loss of weight and condition and reduced breeding success. • Disorientation and behavioural changes can result in reduction in breeding and feeding success. • Fish may be attracted to a facility's light source with larger aggregations increasing predation rates around sea vessels, resulting in loss of species abundance. • Artificial lighting can result in avoidance of nesting beaches by marine turtles and can impact on the ability of hatchlings to orientate after leaving the nest[127,194]. • Artificial lighting may disrupt and disorient sea birds. For example petrel fledglings are known to be attracted to light sources and are subsequently grounded leaving them vulnerable to other threats[129]. v	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) related to continuous light disturbance. • Visual and aesthetic impact to seascape. • Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to light disturbance (e.g. species may be attracted to the lights and then bio-accumulate the toxins released from the facility as well as reducing abundance of fish in surrounding areas) with implications for livelihoods and nutrition (e.g. fisheries, tourism). • Visual and aesthetic impact to seascape.	Minimise	Keep artificial lights to the minimum required to meet navigation and operational safety requirements[112] during decommissioning.
				Minimise	Filter and/or shield lights in order to decrease light intensity for example use hoods and covers to reduce the amount of light spilling[130].
				Minimise	Redirect lighting away from sensitive habitats such as nesting beaches and wetlands adjacent to the port site.
				Minimise	Investigate the effectiveness of coloured lighting and/or adapting the spectrum of lights in reducing the attraction by migratory birds and turtles[113]. For turtles - use light sources that are 'turtles friendly' including very short wavelength light sources (i.e. pure yellow and red sources). Low-pressure sodium-vapour lighting is the purest yellow light source and recommended due to being the best commercially available solution.
				Minimise	Make personnel working on site aware of threatened and migratory species that may be grounded as a result of artificial lighting.
Noise Underwater noise caused by subsea decommissioning.	Avoidance of project area by marine fauna due to decommissioning activities. Underwater noise from decommissioning activities has the potential to displace marine megafauna from critical habitat and interrupt critical behaviours.	• Impacts of noise on marine mammals may be behavioural or physiological. • Behavioural impacts for marine mammals include changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant relationships, masking of biologically important sounds and avoidance of the noise sources[104]. • Physiological effects of underwater noise may include a reduction in animal hearing sensitivity or secondary effects associated with other systems including the vestibular system, reproductive system, nervous system and liver[104].	• Impacts to cultural ecosystem services (e.g. ecotourism, whale watching, reef diving) through presence of noise and vibration. Altered behaviour of species of economic (e.g. commercial fish) or cultural importance (e.g. iconic marine mammals) due to noise and vibration disturbance with implications for livelihoods and nutrition (e.g. fisheries, tourism).	Avoid	Determine what species are likely to be present in an area before commencing decommissioning. Undertake activities outside of sensitive lifecycle periods for relevant species, such as migration, breeding, calving and pupping.
				Minimise	Qualified Marine Mammal Observer (MMO) to be on board in high risk habitats. To prevent a startle response from marine fauna, undertake observations around noise-making operations prior to commencement of work. If species are observed within a site specific exclusion zone delay commencement until individuals clear the area. Only commence surveys during daylight hours when visual mitigation is possible. vi
				Minimise	Use soft start procedures for decommissioning operations whereby the source level is increased gradually before use at full power. The expectation is that nearby animals respond by avoiding the sound source[141].
				Minimise	Use sonar equipped with transducer operating frequency above 200kHz to minimise interference with marine mammals[142].
				Minimise	Use hydrophones to monitor underwater noises from relevant sources. Implement noise reduction measures (non-essential equipment shut down) when cumulative noise load exceeds 120dB@ 250m from vessel (120dB is the threshold at which Mysticeti whales are thought to avoid feeding and breeding activities. US Federal Register 70 FR 1871, 71 FR 3260, and 73 FR 41318)[108].

v The extent of impact will depend on the extent to which sensitive species become accustomed to noise and illumination at night. For example, migratory birds have been known to forage and roost in close proximity to existing port developments.
vi For example, a minimum distance of 350 m in water deeper than 3 m and 150 m in water shallower than 3 m was documented for the Gladstone LNG project.

Source of impact & application in project phase	Outcome of activity	Potential pre-mitigation impact on biodiversity	Potential pre-mitigation impact on ecosystem services	Biodiversity and Ecosystem Services (BES) Impact Mitigation	
				Mitigation Hierarchy Step	Mitigation Activity
Decommissioning workforce Influx of decommissioning employees in previously remote marine environment.	Recreational and / or illegal fishing leading to impact on marine resources.	• Increased pressure on recreational fish species and disturbance to inshore marine habitat and fauna.	• Increased pressure on fish species that are also important to local fishing communities.	Avoid	Locate staff accommodation facilities away from sensitive marine facilities and transport staff to site[134].
				Minimise	Design and implement a bush meat action plan for aquatic bushmeat which includes all products sourced from wild aquatic megafauna. Measures must be context specific but might include the restriction of domestic pets that may prey on native species such as migratory birds or turtles, the employment of beach patrols/eco guards and raising awareness that the harvest of certain marine species is illegal.
				Minimise	Prohibit fishing and hunting on port lease holding, infrastructure and all operational vessels. Prohibit employees and contractors from harvesting or purchasing protected species, e.g. marine turtle products. This should be communicated in a site induction and included in the disciplinary policy.
				Minimise	Restrict access to sensitive marine areas for all employees and the general public in those areas that are directly under company control[134].
				Minimise	Apply restrictions and enforced speed limits for recreational vessels especially in shallow water.
				Minimise	Raise awareness of all decommissioning staff and contractors of environmental sensitivity and legal protection of local environment.

5 Restoration

This section presents restoration in the context of the mitigation hierarchy, defines key principles for effective restoration, lays out the process of restoration planning and identifies some constraints that are specific to the marine environment. A number of case studies are presented from marine restoration projects globally. Restoration can be an important element of biodiversity offsetting, but here we focus purely on the restoration process - further information on BES offsetting which generally occurs off-site[9], can be found in Section 6.


Credit: Pippa Howard

5.1. Overview

Restoration is important to oil and gas operations as one of the key tools for managing impacts to BES and achieving no net loss or a net gain for BES. Restoration techniques can be used to re-establish or improve the ecological integrity and function of ecosystems that have been degraded, damaged or removed by project activity.

The Society for Ecological Restoration defines ecosystem restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed"[207]. The Cross Sector Biodiversity Initiative (CSBI) defines restoration as 'measures taken to repair degradation or damage to specific biodiversity features and ecosystem services of concern following project impacts that cannot be completely avoided and/or minimised[9].

5.2. Planning for restoration

Ecological restoration is the process by which a degraded ecosystem is assisted in recovering towards a pre-defined target state. A good practice restoration project will seek to restore key elements of biodiversity including species and habitats, the ecosystem functions that support them, such as primary production and nutrient cycling, and the ecosystem services that people rely upon. Thus, restoration projects can deliver environmental and social benefits. Restoration is complex, with many uncertainties and generally requires long timelines for results to be achieved. For these reasons it is important to develop a detailed plan that is guided by expert input and is socially acceptable to key stakeholders (see Section 5.4 for the full planning process). Below are several key concepts which must be considered in restoration planning.

Define a reference ecosystem

In developing a restoration plan it will be important to establish restoration targets that are ecologically defensible, and where possible, aligned to a reference ecosystem[9]. Usually, restoration will aim to achieve recovery of an ecosystem along a trajectory towards the identified reference state, which should be identified through extensive consultation with key stakeholders, including BES experts. In the context of an oil and gas project, the reference ecosystem may resemble or improve upon baseline conditions prior to impact. However, it will not always be realistic to expect restored ecosystems to recover to a historic or baseline state, especially when contemporary constraints and conditions cause a site to develop along an altered trajectory. In such cases, defining the reference ecosystem should be a stakeholder-based process and should be aligned to Aichi Targets (i.e. positive outcomes for BES).

Credit: Jeremy Holden/FFI

Assist natural processes

Ecological restoration usually seeks to 'assist recovery' of a natural or semi-natural ecosystem rather than impose a new direction or form upon it. That is, the activity of restoration places an ecosystem on a trajectory of recovery so that it can persist and its species can adapt and evolve[207]. This involves creating the conditions for recovery to occur, including physical conditions such as substrate and water properties, introduction of key species and communities and encouragement of key ecosystem functions, such as decomposition. Once conditions are suitable and the key components have been introduced, natural processes such as reproduction, germination and interaction should drive the recovery of the ecosystem.

Marine restoration is often achieved via manipulating substrate such as relocating sandy sediments from 'excess' deposits to eroded beach locations, or providing hard sub-strata for settlement sites such as artificial reefs[208]. This may be followed by the introduction of key biota that are habitat-forming such as corals, mangroves and seagrass through directly transplanting portions of modular organisms that will continue to grow at a new site, attaching reproductive portions or juveniles to new substrate, or planting seagrass or mangrove seedlings. Where large numbers of species are involved it may be necessary to develop succession plans to sequence species introductions and coordinate the re-establishment of ecosystem function.

Understand the ecological context

In planning restoration, it is essential to consider the ecological context of the site. It's important to understand the historical composition, structure and spatial extent of the reference ecosystem – what was the ecology of the restoration site previously? A review of seagrass restoration activities demonstrated that success rarely occurs in areas that did not at one time support seagrasses[209]. Further, is the site suitable for the species and habitats from an abiotic and a biotic perspective? What is the optimal timing for planting / relocating species, taking into account water temperature, storm patterns and currents? Prior to commencing large-scale restoration projects, it is advisable to develop a map of the historic spatial extent of a given marine habitat and undertake spatially explicit modelling of relevant physical, chemical and environmental characteristics/constraints such as water depth, tidal and current movement, nutrient levels, light availability, substrate type, and wave and current action. Establishing the ecological context will require extensive desk-based research and discussions with BES experts and other stakeholders.

Take an integrated approach

It is vital to take an integrated ecosystem approach to restoration, considering not only habitats and species, but also the ecosystem functions and services that marine habitat provides to people. For example, restored marine ecosystems may provide key services such as sediment stabilisation (e.g. inshore sea grass meadows[210]), shoreline protection from waves and storm surges, water filtration, commercial fisheries, biomass fuel (e.g. mangroves), recreation and tourism (e.g. scuba diving on restored coral reef), or carbon storage to help mitigate climate change. Identifying and integrating ecosystem function and services into the restoration plan from the start will increase efficiency and maximise the social benefits from restoration.

Timing

In a project context, restoration to reduce residual impacts generally occurs on-site after impacts have already occurred and can be undertaken during all phases of a project. Restoration can be applicable at any point of the project cycle and to any disturbed habitat. Whilst restoration activities often occur post-impact, the design, cost and implementation of activities should be considered as early as possible during the project life cycle (i.e. planning and design phase). This is due to the highly variable success rate for restoring certain ecosystems and the need to take into account context-specific conditions. For example, seagrass restoration techniques were ineffective in restoring *Amphibolis* species off the coast of Adelaide, Australia, despite successes elsewhere. It required a decade of trial and error to develop new planting techniques that could successfully restore large areas in this location (Box 18). Further, even where restoration techniques are successful, there is likely to be a significant time lag between project inception and the point at which gains for BES are realised.

5.3. Challenges for marine restoration

Common challenges to the success of a restoration project include ecologically or socially inappropriate planning and implementation, a lack of appropriate effort or resources, or insufficient or inappropriate knowledge and skills[207]. Below, a number of challenges to restoration within marine ecosystems are summarised.

Connectivity

Major differences are evident between how ecosystems are organised on land versus in the sea. For example, three-dimensional movement through the water column is the norm in the marine environment and ocean currents have the capacity to transport organisms (i.e. larvae) for thousands of kilometres[208]. Large-scale movements and complex life cycles must be taken into account when designing a restoration project (see Section 3).

Further, the highly connected nature of the ocean means the restoration site may be affected by external influences including physical, environmental and chemical conditions. Constraining factors may include climate change (i.e. thermal stress leading to bleaching of restored coral reef), poor water quality which may be influenced by diffuse impacts or persistent pollutants in the water or sediments, lack of connectivity between source populations and restoration sites and altered quality (i.e. low stability) of habitat features like sediments[208].

In coastal areas it is important to consider linkages between terrestrial watersheds and the downstream marine ecosystems which may have a strong influence upon inshore marine conditions and ultimately the success of restoration efforts (e.g. run-off from agricultural activities, land clearing and construction). Often these constraining factors are poorly understood and may cause even the best designed and implemented restoration activity to fail. Considerable research effort may be required in order to improve the understanding how and when these factors influence the restoration site, and what can be done to control them.

Mobile species

Restoring species composition in a marine environment can be challenging, especially where highly mobile species are involved. Highly mobile species include marine animals such as whales and dolphins, birds, turtles, some fish, sharks and rays, who by nature travel long distances and have very large ranges. Establishment of the habitat niches that will host mobile species requires knowledge of their life histories and ecological requirements at different stages of their life cycle. Mobile species are also challenging to monitor, as any single restoration site is likely to form just a small part of their entire range, and they may only visit it periodically.

Limited knowledge

Our limited knowledge of the ecology of marine species and habitats, their requirements and their role in the ecosystem can limit the success of restoration efforts, especially in deeper water[211], but also with relatively well-studied habitats. For mangroves, recent research has shown that limited success with restoration is likely to be influenced by nursery conditions and early microbial colonisation patterns in the soil. Experimental trials demonstrated that beneficial soil bacteria were able to colonise mangrove roots in the nursery and survive for an extended time after transplantation – potentially enhancing plant growth and survival[212]. Such applied research is essential to improve our understanding of target habitats and species, and to improve the success of restoration techniques.

Credit: Daniel Jones

Context-specific nature

Restoration in the marine environment is considered technically feasible for some habitats in certain contexts but can be very challenging in others. Many marine ecosystem restoration techniques are only in developmental stages and experimental trials are generally at a small scale, with highly variable success rates. For example, there are few cases of successful large-scale seagrass restoration projects[213]. Restoration techniques are often highly ecosystem, species and context specific and expensive to implement, as demonstrated by the case studies that follow. However, restoration techniques are consistently being improved and encouraging results have been observed with active coral reef restoration in Belize at scales of up to a few hectares (Table 8) and establishment of seagrass at transplantation sites during experimental trials (Box 18). Small-scale restoration pilot studies may be invaluable to gain insight into the success of restoration techniques at a specific site prior to investing in large scale restoration projects.

Determining threats

It is important to consider the reasons for the ecosystem to have degraded in the first place. Are these threats still in existence? Can they be effectively reversed or controlled? The degradation of the ecosystem may have led to a fundamental change in conditions, such that the site is no longer able to sustain the target habitat, for example degradation of the stabilising seagrass habitat on the Adeliade coast in Australia led to high levels of sand movement which made seagrass colonisation impossible (see Box 18). In many cases, controlling the threats that originally degraded the ecosystem, e.g. waste removal, control of alien invasive species, improved water quality and control of sedimentation[214] , becomes a central component of restoration efforts.

Resources

The cost of designing and implementing marine restoration projects demonstrates a significant range depending of the project location and different types of restoration techniques employed. A review of academic literature and technical reports found that the median price for restoration was approximately US$80,000 per ha[215]. The cost of planting seagrass was estimated at AUD $10,000-166,000 (US$7,500 – 125,000) per ha in 2005[216]. Some projects in the USA and Australia that utilised artificial structures to rebuild the ecosystems were reported to cost more than US$ one million per ha. However, investment in restoration in developing countries was observed to be up to 30 times more cost-effective than in developed countries[215]. It should be noted that at this point in time, restoration in deep water areas is almost untested and is likely to be very expensive[211].

5.4. Developing a restoration plan

The following aspects should be considered when planning restoration projects[217]:

- Engage with all key stakeholders in developing the restoration plan, including BES experts, restoration specialists, users of ecosystem services, local communities and regulators.
- Develop a clear rationale for why restoration is required and/or appropriate for the site, considering project BES management targets (e.g. achieving a net gain for BES within a reasonable time frame).
- Understand the ecological context of the site designated for restoration including biodiversity features, ecosystem structure and function and ecosystem services as well as historical and existing threats to the ecosystem.
- Identify the reference ecosystem and determine its major attributes, such as physical conditions, species composition, structural diversity, ecosystem functionality and external exchanges.
- Develop targets, goals and objectives of the restoration project, considering ecological context, the reference site, the BES requirements of the project and the concerns of relevant stakeholders.
- Undertake a constraints analysis to determine site and context-specific factors that will influence restoration success.
- Forecast and allocate future resource requirements including finance, expert personnel, management and ongoing monitoring requirements.
- Develop plans, schedules and budgets for site preparation, installation and post-installation activities.
- Undertake small scale experimental trials to adjust restoration techniques to site specific constraints[210].
- Implement restoration activities, using results of trials to adapt the implementation approach, and applying adaptive management principles.
- Undertake monitoring and evaluation against set performance criteria and indicators. Perform regular reviews of the restoration pathway and implement adaptive management.
- Develop a long-term management plan for the restored ecosystem, including funding and resources needed.

5.5. Case studies

Detailed case studies have been identified for mangrove, coral and seagrass restoration projects in four different locations in order to illustrate restoration techniques and challenges (Box 15 to Box 18). Very few publicaly available examples of successful restoration activities implemented as part of the mitigation hierarchy could be located. The table provides examples from the private sector, non-government organisations (NGOs) and government-led projects.

Box 15: Case Study – Mangrove restoration in Saudi Arabia

Mangrove Transplantation and Restoration Campaign at Tarut Bay, Saudi Arabia (Saudi Aramco)[218].

Mangrove forests in Tarut Bay along the shores of the Eastern Province of Saudi Arabia have declined in extent as a result of man-made impacts in the vicinity of Saudi Aramco's oil and gas production infrastructure. Anthropogenic impacts have included land reclamation (i.e. dredging and land fill operations) and to a lesser degree localised oil spills. King Fahd University of Petroleum & Minerals/Research Institute (KFUPM/RI) and Saudi Aramco conducted trials to determine the survivorship of mangrove seedlings (*Avicennia marina*) transplanted in two surrounding bays (abu Ali Bay and Tanajib Bay).

Trial results showed that transplanted trees could survive, germinate and successfully seed. Survivorship across two years however ranged from 0 to 93% across four sites. The success of transplanted seedlings was strongly dependent on the physical characteristics of the transplantation sites. The most crucial factors were local hydrodynamic and tidal conditions in determining the suitability of sites for mangrove transplantation. Timing of transplantation at this location was also determined to be critical with severe loss of transplanted seedlings in the summer months associated with high seawater and air temperature. Finally, the use of protective tree guards produced higher levels of survivorship by reducing fouling from drift algae and settling barnacles. A tree guard consisted of a mesh wire fence 60 cm in height supported by four wooden stakes about 30 cm apart.

Credit: Pippa Howard

Box 16: Case Study – Mangrove afforestation in the Philippines

Approximately 75% of mangrove habitats have been lost in the Philippines in the last 50 years. The loss of mangroves can be attributed to conversion into aquaculture, harvest of timber for firewood, building material and coastal developments. Large scale mangrove afforestation projects have subsequently been undertaken across the country primarily for coastal protection from typhoons and for wood supply. Studies have estimated that 44,000 ha have been replanted with almost exclusively the genus *Rhizophora* at a cost of USD 17.6 million (USD 400 per ha). A synthesis of the findings of a number of research projects outlined the following lessons learnt[219]:

- *Rhizophora* species were used because of ease of handling and may not require nursery culture. However these species occur naturally in the middle rather than the low intertidal zone, unlike *Avicennia* and *Sonneratia* which are better adapted to seafront conditions. The seedlings were not suited to the selected sites and were exposed to wind and wave damage, erosion of anchoring mechanism, drowning during periods of the year when mean tide levels were high, and colonisation by oysters and barnacles. As such, mass mortalities occurred at numerous sites and those seedlings that did survive performed poorly when compared to those occurring counterparts in the high intertidal zone.

- Locations to replant mangroves were usually chosen in areas least likely to conflict with existing resource use and local interest. This contributed to planting mangroves on available intertidal sandflats, mudflats and/or seagrass meadows i.e. conversion of other productive marine habitats which provided nursery habitat for fish species and foraging for shore birds. These locations were usually within the low intertidal zone and as a result exposed seedlings to mechanical wind stress, wave action and prolonged submersion. In this case the social and economic drivers were complex; however greater consideration of historic distribution and species site compatibility is likely to improve the success of restoration projects.

Box 17: Case Study – Biogenic reef restoration in Yemen

Coral transplantation during the construction of an LNG plant, Yemen

The Yemen LNG Project required the construction of a gas liquefaction plant at Bal Haf Cape, Yemen. The LNG plant involved the construction of the following marine infrastructure: jetty for LNG Carriers loading and shipping; Material Offloading Facility (MOF) for tug boat mooring; sea water intake/outfall pipes; and shoreline protection for the onshore plant.

Environmental baseline studies found that the project area was characterised by diverse coral communities that supported abundant marine life. Project impacts to the coral communities could not be adequately avoided or minimised. As such, coral transplantation was proposed to remove viable coral colonies from the project footprint to receiving sites selected for their close proximity to the original site (i.e. within 100 – 1,100 metres) whilst being outside of the impact zone. Depth, hydrodynamic and water quality conditions were also important criteria in site selection.

In order to increase coral survival, and due to the large size of coral communities, the largest colonies in good health were selectively transplanted, with a focus on the rare, uncommon and/or slow-growing species.

Different methodologies of collection, transport and sticking were employed depending on the colony shape and size. Small colonies were removed by hammer and chisel and transported on a boat in plastic baskets directly to the final location. Large-sized colonies (200 kg up to four tonnes) were removed with a crowbar and lifted to the surface and slowly towed by boat. All colonies were cemented to the new locations using epoxy. In total 1,495 coral colonies belonging to 11 families, 25 genera and 36 species were removed from the direct project footprint.

A monitoring programme was established to measure coral survivorship and adaption to the new environments. Fourteen months after the first transplantation operation in January 2007, 91 % of the transplants were alive and healthy. Evidence of coral growth was also observed soon after transplantation, however there was high variability within and between colonies. Monitoring has observed 95 fish species belonging to 27 families being associated with the transplanted coral systems.

Some coral damage was observed as a result of sedimentation, fish predation on stressed coral, strong swell and current during the monsoon, and fisheries. Whilst the cost of transplanting coral colonies on a large scale should not be underestimated (due to the need to work by hand and specialist nature of the operation), in this case the cost of the transplantation operation was estimated as less than one percent of the total cost to construct the LNG plant and marine infrastructure at Balhaf, Yemen.

Box 18: Case Study – Seagrass restoration, Australia

Seagrass rehabilitation following historic losses off metropolitan Adelaide, Australia[210].

Between 1949 and 2002, in-situ sampling and aerial photography documented a loss of over 5,200 ha of seagrass off the coast of Adelaide coast, Australia. A further loss of 1,800 ha was reported in 2007. Much of the loss occurred in shallow water up to seven metres deep. The primary cause of the loss was considered to be the outcompeting of seagrass by epiphytic algae, which thrived in eutrophic conditions created by anthropogenic nutrient inputs associated particularly with sewage discharges (i.e. nitrogen loads) in the 1970s and 80s[220]. Increased turbidity associated with storm-water runoff also contributed to seagrass losses. The decline of sea grass resulted in adverse changes to coastal processes including increased longshore movement of sand, beach erosion (rapid shoreline retreat and significant loss of beach amenity) and reduced recreational and commercial fisheries stocks which rely on sea grass habitat and primary productivity[210]. As a result of these changes to coastal processes an ongoing government sand management programme has been developed at a cost of AUD$5 million per annum.

A concerted effort was undertaken to reduce nutrient inputs especially nitrogen and particulates into coastal waters. This was achieved by upgrading wastewater treatment plans, closure of ineffective infrastructure and processes such as sludge discharges, implementation of wastewater reuse schemes (primarily for irrigation of horticultural crops and vines and public parklands) and improved storm-water management to reduce particulate inputs to the marine environment. Some natural recovery was observed following the implementation of measures to improve water quality. Early stages of seagrass re-colonisation, covering an area of ~3.65 km^2, were documented around the closed Port Adelaide wastewater treatment plant sludge outfall. Surveys of seagrass extent based on aerial photography illustrated some gain between 2007 and 2013[221]. However natural recovery was not observed in shallower waters. High levels of sand movement that occur following the removal of stabilising seagrass prevented seagrass seedlings from becoming established.

These findings demonstrated that natural recovery was unlikely to lead to significant re-establishment of sea grass across it original extent. A seagrass restoration workshop was convened for local stakeholders, state government agencies, researchers and experts to discuss approaches, challenges and techniques most likely to succeed during assisted restoration trials. Prior to large scale implementation, a series of experimental trials were undertaken by South Australian Research & Development Institute (SARDI – a state government research agency) at several sites off the coast of Adelaide, commencing in 2003.

Credit: Pippa Howard

Seagrass restoration techniques used elsewhere were ineffective due to significant sand and water movement. A decade of trial and error (and subsequent improvement), lead to the development of a new technique that addressed site and species specific challenges. Hessian bags proved effective at proving substrate that allowed the sea grass, *Amphibolis*, to attach to during strong water movement. The stability of the bags was sufficient to allow initial establishment, after which the seagrasses were able to survive and continue to expand without intervention.

This seagrass project highlighted that approaches to restoration that are successful elsewhere may not be successful at a different location. Restoration techniques should be tested and monitored on a small scale and upscaled when stakeholders are satisfied that the approach is likely to succeed. Experimental trials will increase the timeframe of restoration projects but will allow for site specific adaptation, better understanding of the crucial environmental characteristics, ability to investigate cost effective techniques (i.e. inexpensive hessian bags), and reduce the likelihood of a large-scale failure.

Box 19: Case Study – Restoration of provisioning ecosystem services in Madagascar and Mozambique

In southwest Madagascar, Blue Ventures Conservation have been empowering local communities to manage their own marine resources through developing fisheries management plans that aim to sustain local fisheries and safeguard marine biodiversity. They have done this through implementing temporary closures to octopus fishing in designated areas of their fishing grounds, which has led to considerable increases in the productivity of octopus fisheries and, in turn, bigger catches and higher incomes for villagers.

Reef octopuses are rapidly growing species and one of the region's most important stocks, providing a vitally important source of income for coastal communities. They are fished primarily by women and sold on to export markets. During the temporary closures which covered approximately 20% of a village's fished area and lasted for 2-3 months, traditional local laws established by community committees enforced the no-take rules. When an area was re-opened for fishing, individual octopus catches increased by almost 90% and village-level fishing income more than doubled in the month following each closure (compared to control sites where no fishing grounds were closed) and with no significant decline of income noted during closure periods[222]. However, villages with high rates of poaching during closures experienced reduced economic performance, thus highlighting the importance of local level buy-in and enforcement to accrue benefits from closures.

Temporary closures that target rapidly growing species are a good management tool to engage a large number of community members because they offer quick and tangible results, and this can play a powerful role in building support for locally led fisheries management and marine conservation. Following the rapid uptake and success of the periodic fishery closure model in southwest Madagascar, this management model was replicated in communities along the country's southern, western and northern coastlines, and many of the communities that engaged in octopus closures moved on to establish a broader range of community-based and co-management actions. For example, within three years of implementing octopus closures, the village of Andavadoaka had joined together with surrounding villages to create a locally managed marine area (LMMA) known as Velondriake. This LMMA was formally gazetted and represented by an elected committee. Management practices included the extension of the periodic closure regime into mangrove habitats; the banning of destructive fishing methods; and the founding and community enforcement of six no-take reserves[223,224].

Using a similar model, the Zoological Society of London (ZSL) has been working with communities in northern Mozambique to create temporary octopus closures. Here, alongside the temporary closures, communities have also created smaller permanent octopus reserves (i.e. areas that are permanently closed to octopus fishing). These permanent reserves act as 'replenishment zones', which, through the effect of spill-over whereby individuals from a marine reserve move to adjacent fishing grounds, help to replenish octopus in temporary reserves once stocks have become depleted following the opening of temporary closures[225]. The creation of permanent no-take zones (NTZs) in key areas such as spawning, nursery, feeding or sheltering habitats can greatly help to reduce pressure on coastal marine ecosystems, and they offer a valuable way in which to help to restore degraded marine habitats and populations, and the ecosystem services they provide. NTZs can be used alongside conventional fisheries and conservation management measures. They may exist in isolation and be surrounded by normal fishing grounds, or form part of a larger marine reserve that is managed for nature conservation with managed buffer zones around the NTZ.

Table 8: Further case studies for marine restoration

Project name	Location	Restoration activity	Source of information
HubLine Eelgrass Restoration at Salem Sound and Boston Harbor	Boston, USA	Restoration project to restore eelgrass to Salem Sound and Boston Harbor, funded as partial mitigation for Algonquin's HubLine pipeline impacts to eelgrass in Beverly Harbor. Restoration techniques involved: • Developing a site selection model that utilised existing information including historical eelgrass presence, nearshore stressors, wave energy, sediment type and some field data in a GIS-based assessment. • Successfully establishing test-plots at locations selected using the site selection model. • Undertaking reconnaissance dives to delineate the most suitable planting area within the site. • Designing seasonal planting schedule, planning methods, harvesting methods from donor sites. • Full scale planting of eelgrass at the pipeline impact site. • Additional planting at numerous sites (not related to mitigation actions). • Monitoring of transplant, reference and donor beds.	http://www.mass.gov/eea/docs/dfg/dmf/programsandprojects/marinefisheries-hub3-eelgrass-2012-annual-and-mid-project-report-to-dep.pdf
Restoration of fish habitat (transplanted seagrass) in Indian River Lagoon	Florida, USA	Restoration led by an environmental consultant in response to the construction of a new navigation channel and historic seagrass losses to harmful algal blooms and other environmental factors. Restoration techniques involved: • Developing a comprehensive seagrass mitigation and monitoring program. • Harvesting rapidly growing seagrass, from a donor site using only hand tools and then manually installing the grass at the recipient study sites. • Protecting transplanted seagrass with mounted metal cages from manatees and turtles.	http://www.atkinsglobal.co.uk/en-GB/media-centre/news-releases/2014/jan/2014-01-27
Virginia Coast Reserve's Oyster and Seagrass Restoration	Virginia, USA	Restoration led by NGO/university actors of functional reefs and seagrass beds within coastal bays following long term decline. Restoration techniques involved: • Dredging and planting fossil oyster shells to provide the substrate needed for recruitment of young oysters. • Developing and refining of marine-friendly, stackable, interlocking concrete block which enabled recruitment of oyster spat. • Harvesting of 38 million seagrass seeds and planting of 317 acres of eelgrass in four coastal bays. • Creating no-harvest sanctuaries in the coastal bays. Outcome: Restored seagrass to over 4,500 acres of the coastal bays. And restored 47 acres of functional intertidal oyster reefs.	http://www.nature.org/ourinitiatives/habitats/oceanscoasts/restoration-works.pdf
Florida Keys' Staghorn Coral Restoration	Florida, USA	Restoration led by NGO/university actors of two coral species which had declined in the Florida Keys National Marine Sanctuary. Restoration techniques involved: • Establishing an underwater coral nursery three miles off Key Largo, Florida, later expanded to other nursery sites. • Growing fragments of naturally occurring and wild coral in nurseries and transplanting these fragments back onto reefs once they had grown to a suitable size and been quarantined for disease.	http://www.nature.org/ourinitiatives/habitats/oceanscoasts/restoration-works.pdf
Reef Restoration at Laughing Bird Caye National Park, Southern Belize	Belize	Restoration of coral reef at Laughing Bird Caye, Belize. Coral reef ecosystems had been degraded by coral bleaching events, hurricanes and earthquakes. Project goals included increasing abundance of Acroporid coral species, and restoring lost ecosystems services at Laughing Bird Caye National Park (i.e. shoreline protection, habitat for marine creatures, and aesthetic value for tourism). Restoration techniques utilised included: • Establishing six different nursery locations were in Southern Belize. In-situ coral propagation occurred at these sites which involved growing the corals in the natural environment. Corals were attached to frames anchored to the sea floor at depths ranging from 2 – 9 feet deep. • Coral fragments and nursery locations were chosen in varied locations to maximise coral adaptions and resilience to climate change (i.e. coral bleaching events). • Out-planting of approximately 4,000 Acroporid fragments has occurred at Laughing Bird Caye National Park in three large scale efforts undertaken in 2010. • Regular monitoring of both nurseries and out-plants to remove algae removal, especially in the hotter months and to undertake predator removal, and make observations of disease or bleaching. Outcome: After one year, coral growth was observed at the nursery sites. Corals grew fastest in the shallower settings. The corals were adversely affected by natural hurricanes, predation and bleaching events which occurred between 2008 – 2010 at the nursery and out-planting locations. Monitoring observed partial/full bleaching on some coral and some mortality, although many individuals recovered. The results indicated that coral hosts relocated from shallower inshore waters may lend adaptive resilience to thermal stress i.e. reduce the impact of bleaching events.	http://floridakeys.noaa.gov/review/documents/erbelizecasestudy.pdf

Project name	Location	Restoration activity	Source of information
Coastal habitat creation and water quality improvements to protect and enhance the Gold Coast Broadwater	Gold Coast, Australia	Local government lead (i.e. Gold Coast City Council) project was undertaken in response to historic degradation and recent parklands expansion which required reclamation of marine environment. Activities include a combination of restoration and offset actions required as a result of statutory approvals process triggered under various pieces of local and state legislation. Mangrove habitat creation at an existing degraded stormwater outfall – creation of a 1.2 ha mangrove habitat area to provide intertidal fish habitat and reduce fine sediment to enhance seagrass colonisation.	http://www.qldcoastalconference.org.au/2011/HallJ_055.pdf
Ras Laffan Seagrass Remediation Project	Doha, Qatar	Restoration of seagrass and seagrass communities in Ras Laffan coastal area. Approximately 300 m^2 of seagrass transplanted to safe zone area.	http://www.aljamali.net/projects.php
Ras Abu Fintas Seagrass Project	Ras Abu Fontas, Qatar	Transplantation of seagrass as a compensation for the seagrass loss in Ras Abu Fontas (RAF) – Coastal area. Approximately 150 m^2 of seagrass transplanted.	http://www.aljamali.net/projects.php
West Bay Lagoon	Doha, Qatar	Restoration of seagrass and seagrass communities in West Bay Lagoon. About 100 m^2 of transplanted to safe zone area. Research for transplantation method.	http://www.aljamali.net/marine-restoration/seagrass.php (Al-Jamali et al. 2005, 2006).


Credit: Michangelo Pignani/FFI

5.6. Useful resources

Society for Ecological Restoration (SER), Science & Policy Working Group (2014) Guidelines for Developing and Managing Ecological Restoration Projects (2nd Edition) describes some of the more important considerations for the design and implementation of restoration projects. Available at **http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration**

Edwards, A.J. (ed.) (2010). Reef Rehabilitation Manual. Coral Reef Targeted Research & Capacity Building for Management Program: St Lucia, Australia. ii + 166 pp. Available at **http://www.reefresilience.org/pdf/Reef_Rehabilitation_Manual.pdf**

Edwards, A.J., Gomez, E.D. (2007). Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. iv + 38 pp. Available at **http://www.reefresilience.org/coral-reefs/management-strategies/ecological-restoration/restoration-of-coral-reefs/**

BMT Oceanica Pty Ltd (2013) Transplanting Posidonia Seagrass in Temperate Western Australian Water: A Practical 'How to' Guide. Available at **http://www.bmtoceanica.com.au/products/seagrass-transplanting-manual**

6 Biodiversity offsets

This section introduces biodiversity offsets and their application in coastal and marine environments. In line with international best practice a flexible and principles-based approach to offset design and implementation is recommended. We summarise key implications of the GPG's 10 core principles for biodiversity offsetting and introduce a further four principles that are specific to biodiversity offsets:

Principle 11 Limits to biodiversity offsets
Principle 12 Offsets deliver outcomes for biodiversity that are additional
Principle 13 Offsets support long-term, durable outcomes
Principle 14 Ecological equivalence is maximised

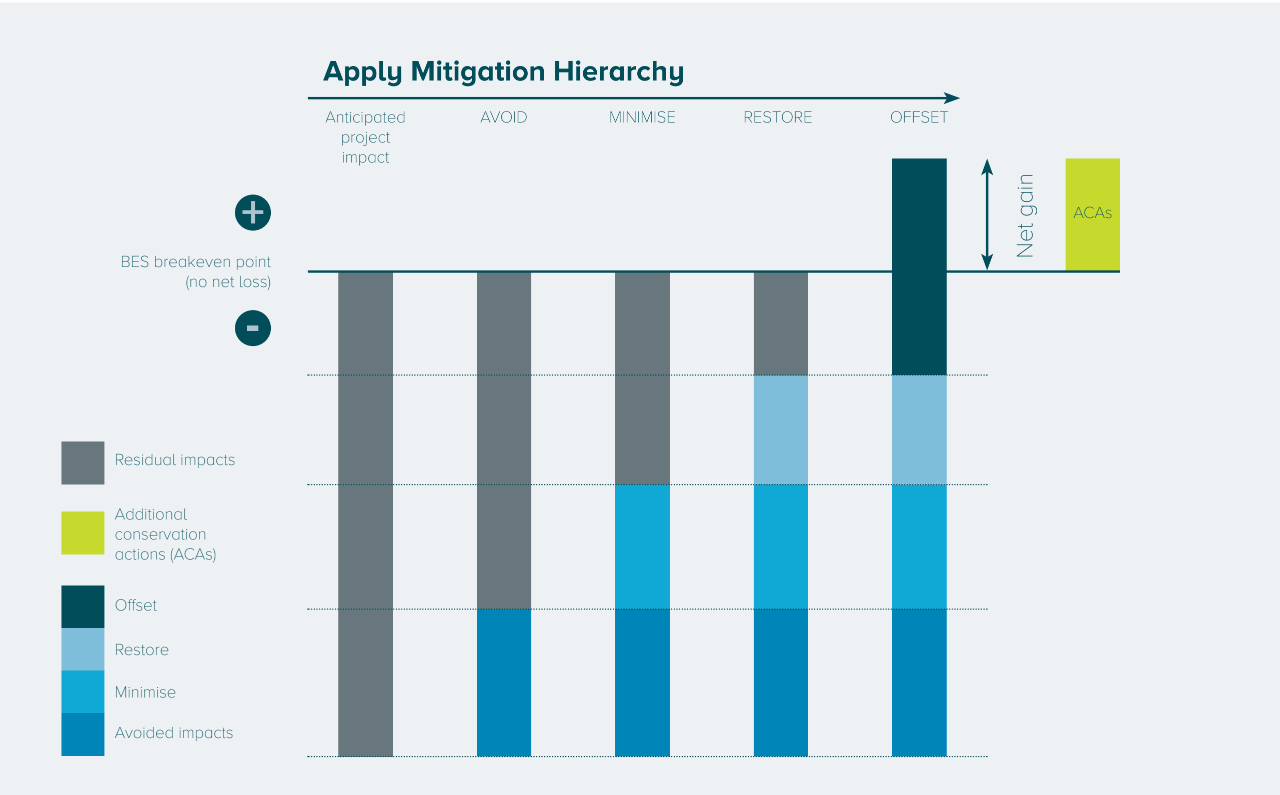
The main steps in a good offset process are summarised and potential options and activities in a marine context are highlighted. This section is designed to complement other existing guidance on biodiversity offsets and readers are directed to relevant resources for further information and support.

6.1. What is biodiversity offsetting?

Applied within the mitigation hierarchy framework, biodiversity offsets are intended to help counteract the adverse impacts from a project development where significant residual impacts on biodiversity are expected to remain after all avoidance, minimisation and restoration measures have been applied (see Figure 12). In simple terms, biodiversity offsets can be regarded as additional conservation activities explicitly linked to one or more development projects that are causing some loss of biodiversity and designed to compensate for anticipated unavoidable damage to species and ecosystems by those projects[226,227].

The goal of many biodiversity offsets is to achieve no net loss of biodiversity or preferably a net gain, in comparison to the baseline situation before the original development project is implemented (Figure 13). No net loss or net gain are typically assessed in terms of the area conserved and its species composition, habitat structure or types, ecosystem functions, and people's use and cultural values associated with the biodiversity[228]. Unlike other forms of compensation, biodiversity offset activities are designed to achieve measurable or verifiable biodiversity conservation outcomes on the ground or in the water (outside the footprint of the development project)[228].

Figure 12: Biodiversity offsets and the mitigation hierarchy.
Biodiversity offsetting is the final step in the mitigation hierarchy and a last resort for counteracting the adverse residual impacts of project development on biodiversity after all avoidance, minimisation and restoration measures have been applied. Offset activities should contribute to achieving no net loss of biodiversity (i.e. no overall harm) or preferably a net gain (i.e. make a positive contribution to biodiversity conservation). Note that Additional Conservation Actions (ACAs) are activities intended to benefit biodiversity but the effects or outcomes may be difficult to quantify.



Offsets can take many forms and involve a range of defined activities intended to secure conservation outcomes. These generally fall into one of two kinds of intervention:

- **Positive management interventions or restoration offsets** that aim to restore or rehabilitate a degraded habitat or ecosystem and/or support the recovery of a threatened population[226]. Whilst marine restoration techniques are in early development and show variable success[213], under favourable conditions the restoration of ecological structure and function can be more rapid in some marine ecosystems (e.g., mangrove, seagrass, coral reef) than in many on land (see Section 5 for further discussion on restoration of marine ecosystems).

- **Averted loss offsets** (also referred to as avoided loss or protection offsets) aim to reduce the rate at which biodiversity is being lost within the land or seascape due to other current and future pressures (independent of project impacts)[226]. This typically involves actions to protect an ecosystem, habitat or species (located outside the footprint of the development project). For averted loss offsets to be defensible, it must be shown that ongoing or impending threats are imminent and will have significant adverse impacts on biodiversity.

Further information on biodiversity offsets – what they are and guidance to support good practice design and application – is available (see Box 19)

Box 19: Further resources on biodiversity offsets

1. FFI's biodiversity offset film provides an introduction to biodiversity offsets within the context of the mitigation hierarchy and is available from **http://www.fauna-flora.org/initiatives/business-biodiversity-resources/** in English, French, Spanish and Portuguese.

Credit: Mark Moynihan/FFI

2. The Business and Biodiversity Offsets Programme (BBOP) has developed a range of guidance to support good practice offset design and application. The Standard on Biodiversity Offsets aims to assist offset designers in the planning and implementation of an offset to meet best practice. The Standard and supporting guidance are available from: **http://bbop.forest-trends.org/pages/guidelines**
3. The World Bank Group has published a biodiversity offsets users guide providing introductory guidance on different types of biodiversity offsets and how to use them effectively.
4. The International Union for Conservation of Nature (IUCN) global policy on biodiversity offsets provides a high-level framework to guide the design, implementation and governance of biodiversity offset schemes and projects. Specifically, it provides guidance as to where offsets are, and are not, an appropriate conservation tool. **Supporting technical papers**[229,230,231] are available.
5. The International Council on Mining and Metals (ICMM)'s independent report on biodiversity offsets[232] provides an overview of key issues regarding biodiversity offsets, sets out pragmatic ways forward and shares some of the mining industry's biodiversity offset experience.
6. BBOP hosts a community of practice which provides a network, forum and webinar series for the growing number of organisations and individuals working on various aspects of the mitigation hierarchy, including biodiversity offsets. Its purpose is to facilitate the sharing of practical experiences, skills and lessons learned.
7. FFI's report series on lessons learnt in biodiversity offset policy and practice is available from: **http://www.fauna-flora.org/initiatives/business-biodiversity-resources/**

6.2. Biodiversity offsetting in the marine environment

Drivers for the increased uptake of marine offsets

The uptake of biodiversity offsetting, as a mechanism to counterbalance the impacts of development, has increased rapidly around the world in recent years. Drivers include regulatory requirements for mitigating or offsetting ecological harm which are becoming commonplace, with more than 60 countries having introduced relevant policies[231,233]. Many international financial institutions also make provision for offsets as part of their approach to risk management and a growing number of companies have made commitments to no net loss or net gain for biodiversity[12].

The rationale and objectives of biodiversity offset schemes in different jurisdictions vary considerably. Some focus on the protection of threatened species or habitats whilst others take more integrated approach that emphasises the maintenance or enhancement of biodiversity, ecosystem function and ecosystem service provision. Existing and emerging legislation that requires or makes provision for biodiversity offsets typically applies to marine environments under regional or national jurisdictions. In countries with coastlines and marine resources it is important that the mitigation hierarchy, including offsets, is legislated and applied appropriately for the marine context.

Marine specific offset requirements and guidance have been developed in some cases (e.g. the State of Queensland in Australia has marine-specific offset requirements for developments that impact marine fisheries resources, fish habitat or marine plants[234] and the Canadian Department of Fisheries and Oceans, which regulates fish habitat compensation, has produced guidance for fish habitat compensation to achieve no net loss[235]).

The need to develop separate offset policy, or at least policy guidance, for the marine environment is gaining recognition[236] and the emergence of coastal and marine specific offset guidance, particularly for coastal regions and island states, is increasing[237,238]). With expected growth in the offshore oil and gas sector, alongside other industries (shipping, fisheries, tourism, port and coastal developments, renewables, infrastructure, mining etc.) marine-specific offset requirements are likely to become a more common and prominent feature of local, national and regional policy and legislation in future.

Marine vs terrestrial offsets

There is a growing body of scientific research on technical and methodological aspects of biodiversity offsetting[230,232]. Practical experience in the development and implementation of biodiversity offset policy is also being shared (see useful resources in Box 19). However, to date, experience in biodiversity offset policy and practice has largely focussed in terrestrial settings. Biodiversity offsetting in the marine environment is a relatively new field but one that is subject to increasing research and application.

Whilst many lessons learnt from terrestrial offset experience are transferable to the marine environment, fundamental differences between marine and terrestrial ecosystems (see Section 3) mean that marine offsets can be more difficult and may demand different design and implementation approaches. Difficulty stems from:

- greater connectivity and larger scales of movement – of individual living organisms, nutrients, sediments and pollutants - compared to terrestrial systems creates challenges for marine offsets (see Section 3.1, Box 20 and Figure 14).
- the complexity of marine species, communities and their interactions similarly present opportunities and constraints for marine offsets (see Section 3.3, Box 21 and Figure 13).
- the wide range of spatial and temporal scales over which ecological processes in the marine environment operate, such that system behavior is highly contextual[239]. Approaches to marine offsets thus need to be flexible and designed for specific local circumstances.
- the dynamic relationship between people and marine systems and the tenure systems that define who can use what resources for how long and under what conditions. These will be very context specific and strongly influence offset implementation models. One commonality across the marine realm, is that there will be limited (if any) scope to directly purchase marine areas for protection as part of offset activities – a common strategy for land-based offsets. Alternative approaches thus need to be explored in close collaboration with government and civil society stakeholders.
- scale issues relating to jurisdictional boundaries.

Box 20: Connectivity considerations for marine offsets

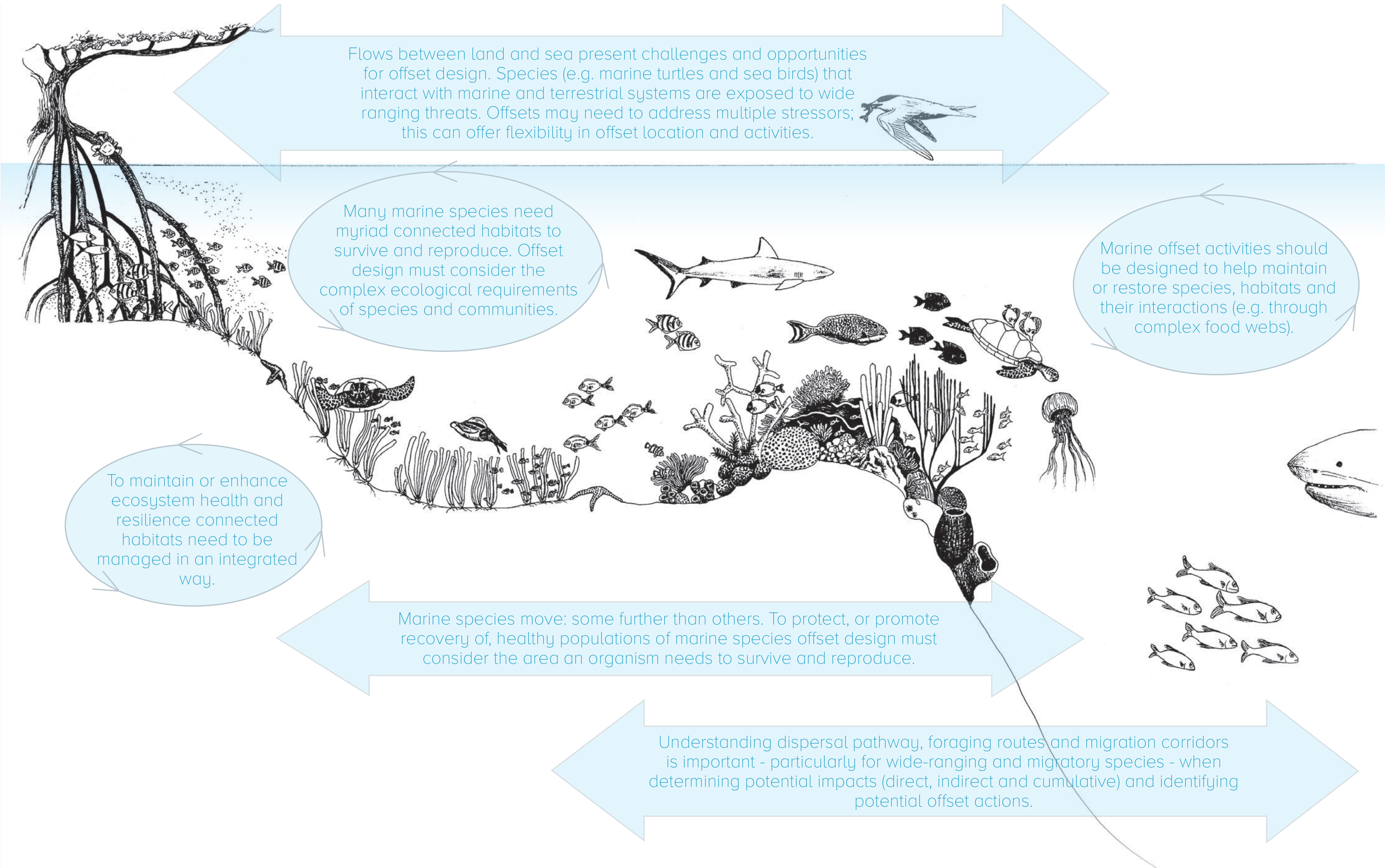
Connectivity is essential for supporting dispersal, local movement and seasonal migrations for food, mating and production of offspring (see Figure 13). In many cases, marine species need myriad different connected habitats to survive and reproduce successfully. Understanding patterns of connectivity among ecosystems and the scale of movement of different species will be critical in the design of marine offsets that seek to establish or extend marine protected areas or improve connectivity among existing ones[240]. For example, connectivity among populations of reef species (fish, invertebrates and corals) is primarily due to larval dispersal. The scale and pattern of larval exchange (e.g. through local recruitment and long distance dispersal) has implications for the design of marine protected areas (size, shape, location) within a network[240,241,242].

Some marine species require larger areas than others to eat, live and reproduce. Leatherback turtles, for example, are among the widest ranging large marine vertebrates in the world and have been recorded to travel thousands of kilometers; circumnavigating entire ocean basins[243,244]. Offsets that seek to provide in-situ conservation for such highly mobile and wide ranging species at a single location may thus prove ineffective. For example, protecting the end-point of a migration route may fail to achieve intended conservation outcomes if important migration corridors are not considered and are compromised by other pressures. In such cases, offset activities may be best targeted to places in the migratory pathway where the species show greatest vulnerability[245].

Connectivity between habitats is important for supporting ecosystem function and building resilience to climate change and other impacts. Mangroves in the Caribbean, for example, have been shown to increase the resilience of offshore coral reefs in response to disturbances such as hurricane damage. Mangroves serve as important fish nurseries maintaining stocks of the herbivorous fish that eat algae in coral reefs. Without these fish the algae may outcompete corals for space after a disturbance event[246]. Linked habitats therefore need to be considered and managed as parts of a single functional unit[242] when designing and implementing offsets. Connectivity between habitats also means that conservation gains from offset activities in one area may be realised in adjacent marine systems[245].

Impacts and pollutants also flow within and between marine ecosystems and across the land-sea interface. Consequently, marine offsets and the biodiversity they seek to conserve may be particularly vulnerable to disturbance (e.g. from waterborne pollutants[213] and alien invasive species) and diffuse impacts (e.g. sediment and nutrient caused by run-off from land-based activities). The scale over which impacts occur can also be considerable larger than in terrestrial systems and offset activities may need to be effected over large spatial scales to achieve intended conservation outcomes. Direct impacts on marine species or habitats at one site can also result in indirect impacts occurring large distances up- or down-current. Marine ecosystems are thus much more prone to impacts from distant impact sources and cumulative impacts than are terrestrial habitats. This can complicate measurement of losses and gains where these are occurring far from project sites and make it more difficult to control the outcomes within a marine offset site[245]. Limitations in our understanding of biodiversity sensitivities and likely responses of marine species, communities and ecosystems to diverse and diffuse threats will contribute greater uncertainty when determining likelihood of offset success; adopting a precautionary approach is essential.

Figure 13: An illustration of connectivity and complexity in marine ecosystems and its implications for biodiversity offsets (see also Boxes 20 and 21 and references therein).



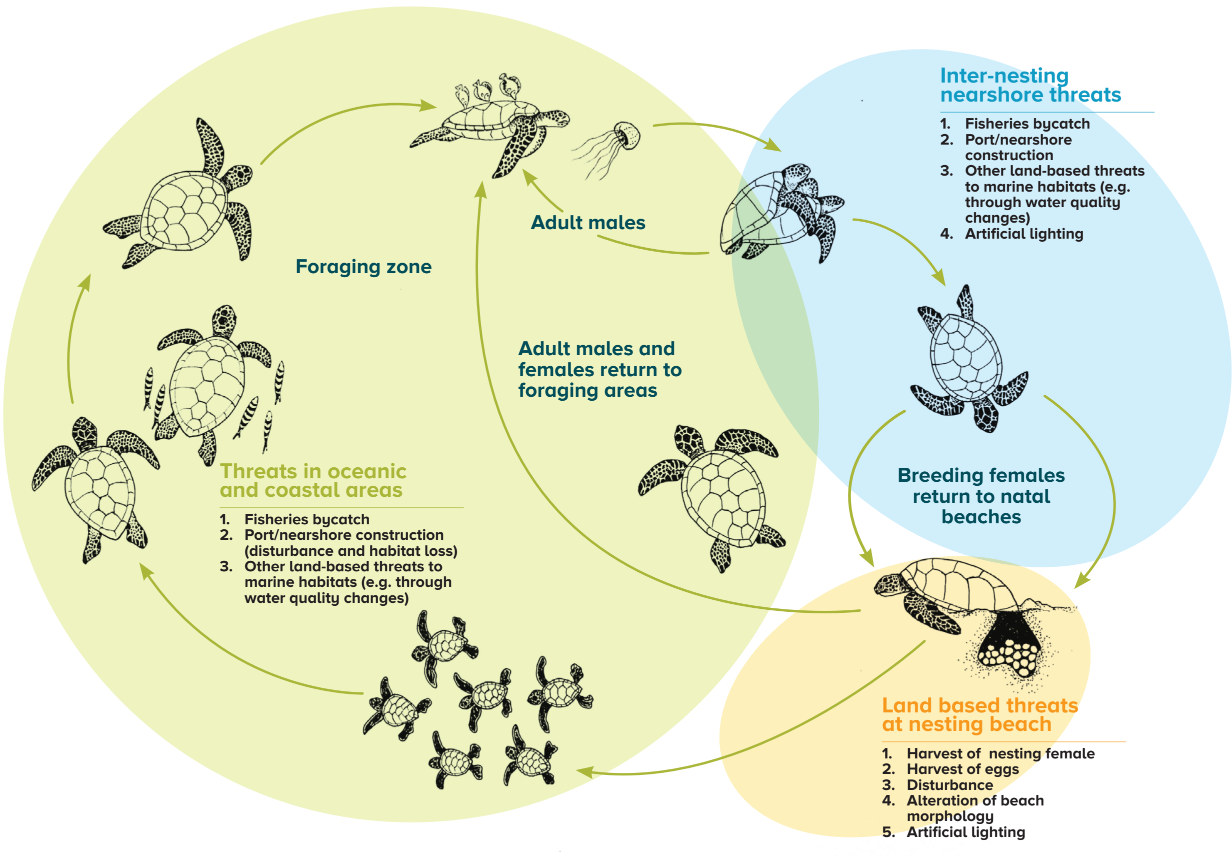
Box 21: Complex life histories and communities - implications for marine offsets

Many marine species have complex life histories and use different habitats (marine, freshwater and terrestrial) at different phases in their life cycle. As a result, many marine species are exposed to a diverse range of threats over different spatial and temporal scales (see Figure 14). The location(s) and design of offset projects needs to consider the complex ecological requirements of species and communities and the full range of threats they face. For many marine species, maintaining the health of myriad ecosystems will be crucial if they are to survive and thrive. Offset activities that address multiple stressors may be required to achieve intended conservation outcomes. Such considerations, whilst challenging, can offer greater flexibility in the location of offsets[247] and a wider range of possible offset activities in marine compared to terrestrial systems (see for example Box 29).

The structure and function of marine ecosystems relies upon a complex network of interactions among individuals and groups of organisms[67] (see Figure 13) with different marine species playing different ecological roles within the ecosystem/s they interact with (see Section 3.3 and Figure 6). Key ecological processes involving the interactions among species and with their environment (e.g. complex food-web interactions, reproductive cycles, population connectivity and recruitment) play an essential role in maintaining marine ecosystem function, supporting thriving communities, and maintaining the resilience of an ecosystem to shocks and disturbances. Marine offset activities should be designed to help maintain or restore species, habitats ***and*** their interactions. In this way, offsets can work to build resilience into an ecosystem.

Top predators, ecosystem engineers, and species that link marine and terrestrial systems play particularly important roles in determining the composition, structure and function of marine ecosystems[7]. Offset activities targeted at the conservation or recovery of such highly interactive species, when designed and implemented as part of an ecosystem approach, have potential to deliver important conservation gains by helping maintain and/or restore ecosystem function and resilience. Proponents should, however, also be alert to possible unintended consequences of offset activities in marine ecosystems as small changes for highly interactive species may be magnified across the system.

Figure 14: Marine turtles face a wide range of different threats over the course of their lifetime. The design of offset activities and selection of sites needs to consider the complex ecological requirements of keystone species, such as turtles, and the full range of threats they face (note that this figure highlights a range of threats; it is not intended to show all threats facing marine turtles).



6.3. Good practice principles for offsetting

There is no single best way to design and implement biodiversity offsets and a flexible, principles-based approach is recommended[248]. In this section, key implications of the 10 GPG principles (introduced in Section 2) are discussed and a further four principles specific to offsets are introduced.

Principle 1: Do no harm and be proactive in making a positive contribution to BES conservation

- Biodiversity offsets should fully compensate for adverse residual impacts to ensure no overall harm. It is generally expected that biodiversity offsets should achieve, at a minimum, no net loss and preferably a net gain for biodiversity. Outcomes should be objective, measurable and verifiable[i].
- Biodiversity offsets can be designed through stakeholder consultation towards achieving local, ecosystem-based and/or national objectives (see, for example, 'aggregated offsets' in Section 6.5). BES outcomes need to be measured and determined in time and space relative to impacts and to the objectives set. This is important in the marine environment, which is dynamic and connected.
- Biodiversity offsets can include biodiversity components selected because they provide important ecosystem services, helping ensure the offset design delivers no harm or a positive contribution to the provision of ecosystem services[248,249] (see Box 22).

Box 22 : Biodiversity offsets and ecosystem services

Biodiversity underpins ecosystem services, both directly (e.g. fish stocks or seaweeds for harvest) and through its role in maintaining ecosystem function (see Section 3.5). Opportunities exist for offsets in marine contexts to deliver benefits for both biodiversity and ecosystem services (e.g. offset activities designed to protect or restore mangrove habitat can have positive effects on fish stocks and regulatory services such as storm protection).

A good offset design process will take into consideration the loss and gain of biodiversity at all levels of organisation, and how changes in ecosystem composition, structure and function might influence the flow of ecosystem services to different stakeholders over space and time[248] (see also Principle 4). Explicit consideration will be given to the social and cultural values of biodiversity. This requires an understanding of ecosystem service dependencies (i.e. who utilises or benefits from different ecosystem services over space and time) and how these might be affected (positively or negatively) by both the development project and potential offset/s.

For offsets designed to compensate for project impacts on biodiversity and ecosystem services, the proximity of offset and impact sites requires careful consideration. Biodiversity offsets are typically located in an area that is separate and distinct from the original project site. Offset areas located close to impact sites will sometimes serve to maintain ecosystem services utilised by the same beneficiaries affected by the development project. However, many site-specific ecosystem services might not be sustained or replaced by a biodiversity offset[227]. In most cases, a suite of compensation measures (in addition to the offset) will be required to compensate for the local loss of ecosystem services resulting from the oil and gas project.

Offset activities can have adverse effects on local stakeholders through their effects on ecosystem services (e.g. by restricting access and use of marine resources). Good practice social impact assessment is needed to support the identification of risks and adverse impacts of offsets for ecosystem services at an early stage so that these can be prevented or mitigated[250,228] (see also Principle 7). Adverse impacts on ecosystem services that are highly irreplaceable should be avoided.

Principle 2: Apply the mitigation hierarchy

- The mitigation hierarchy should be applied with clear recognition that there may be many impacts to marine BES cannot be offset. These impacts need to be avoided, as this may be the only means to prevent irreplaceable loss.
- The mitigation hierarchy is to be followed sequentially – avoid, minimise, restore and, as a last resort, offset impacts. All options to avoid and minimise impacts should be fully considered, including the 'no project' option.
- Offsets should never be used to circumvent taking action to avoid and minimise damage to BES or to justify projects that would otherwise not happen.

i To demonstrate that offset activities have contributed to achieving no net loss or a net gain, residual impacts and conservation gains (achieved through avoidance, minimisation, restoration and finally offset activities) need to be measured and verifiable.

Principle 3: Apply mitigation planning within the seascape context

- The scoping, design, implementation and monitoring of biodiversity offsets should consider the wider seascape context and, where applicable, land-sea interactions if they are to achieve intended conservation outcomes.
- Understanding of the seascape context, land-sea interactions and the nature of direct, indirect and, crucially, cumulative adverse impacts on marine ecosystems over much wider spatial scales than the site of operation should inform the scoping of offset options and help determine external constraints and opportunities for achieving long-lasting conservation outcomes.
- Priority areas identified through national biodiversity frameworks or strategies, species or habitat action plans and systematic conservation plans can help identify offset options within the land and seascape[251,252]. In this way, offsets can be designed to directly contribute to seascape conservation goals.
- Taking account of the seascape context can support identification of opportunities for the aggregation of offset activities and sites by more than one developer with the aim of maximising conservation gains.
- Offset policies should require regional seascape planning to select offset implementation sites[253].

Principle 4: Apply an ecosystem approach

- A holistic approach to offset design and implementation should be applied that considers land, sea, living resources and people in an integrated and adaptive way. The system is considered as a whole with emphasis on maintaining or enhancing ecosystem function and resilience, rather than individual species or habitats.
- Sound ecological understanding must underpin the design and implementation of marine offsets, taking into account key spatial and temporal ecological aspects, e.g. life histories, community dynamics, migratory routes, and necessary biophysical characteristics (see Section 3 and Boxes 20 and 21).
- The identification of: i) opportunities and constraints for designing offsets to deliver biodiversity and ecosystem service benefits (see Box 22) and ii) potential adverse impacts of offset activities for local stakeholders will be essential[228,250,254].
- A good offset process will draw on the best available marine ecological and ecosystem information and expertise throughout.

Principle 5: Maintain or enhance connectivity

- Connectivity considerations (see Box 20 and Figure 13) should be a core concern throughout marine offset planning and implementation processes.
- Maintaining connectivity at appropriate spatial and temporal scales will be essential for supporting viable populations and ecosystems and for building the resilience of offset sites and the biodiversity they seek to conserve.
- Conservation gains resulting from offset activities may be realised in other ecosystems located near or far from the offset site. This can present challenges for the sustainability of conservation gains and for the monitoring and measurement of gains resulting from offset activities.

Principle 6: Go beyond compliance

- Good practice biodiversity offset guidance is available (see Box 19 for example) and should be consulted to support the robust design and implementation of biodiversity offsets.
- Good practice guidance for conservation and management of marine biodiversity and ecosystem services and relevant guidance should be consulted.
- Advances in marine offset policy and practice at national or regional levels can support improvements in marine offsets elsewhere.

Principle 7: Follow best practices for stakeholder engagement

- Follow best practice to enable the meaningful and inclusive participation of stakeholders and rights-holders in decisions relating to the assessment and selection of potential offset sites, design and implementation of activities, and monitoring. This can help build positive relationships between project developers and local stakeholders, improve support for offset sites and activities, facilitate the integration of local knowledge and values, and in turn contribute towards more sustainable, long-term conservation outcomes.
- Broad stakeholder consultation is essential to: i) understand the way in which different stakeholders utilise, depend on and value biodiversity and ecosystem services; ii) assess the social impacts of any proposed offset/s; iii) identify and build consensus on potential synergies, trade-offs and compromises; and iv) explore opportunities for maximising participation in the early assessment, planning, implementation and monitoring of offsets.
- Concerns of affected communities at the development project and offset site/s must be addressed through direct consultation and participatory processes; noting that social science approaches to such assessments will differ from scientific assessments. The right of indigenous peoples and other local communities to free, prior and informed consent must be

respected and rights based approaches followed (see Box 3 in Section 2). Where offsets affect the rights of indigenous peoples and local communities, free prior and informed consent (FPIC) needs to be obtained.

- The involvement of biodiversity offset experts and local, regional and/or international experts in marine science, ecology, conservation and ecosystem services can greatly improve scoping (i.e. identification of offset options in the land and seascape), feasibility and design of offset activities.

Principle 8: Ensure a robust baseline for marine BES

- Establishing a robust and defensible BES baseline at the appropriate scale, scope and depth is essential for determining potential impacts and mitigation options and for the measurement and monitoring of BES losses resulting from project impacts, and gains achieved through mitigation actions, including offsets.

Principle 9: Apply a precautionary approach

- Biodiversity offsets in the marine environment can be complex, expensive and uncertain in outcome. A precautionary approach to mitigation is paramount and a broad set of avoidance and minimisation measured should be prioritised.
- It is important to draw upon best available information and expertise, and broad stakeholder consultation, when determining potential offset options and likelihood of achieving intended conservation outcomes.
- Ecological restoration of marine ecosystems is in its infancy and can be uncertain in outcome and sustainability (see Section 5). A precautionary approach must be applied when using predictions of successful restoration as part of the mitigation hierarchy in calculating the residual impact that must be offset (i.e. restoration success should not be overestimated).
- Wherever possible offsets should be implemented (or under implementation) with demonstrated contribution toward intended conservation outcomes *before* impacts occur. Without these safeguards, there is a significant risk that the impact occurs but the offset is never realised or that time-lags between losses and gains compromise the ability of affected species and systems to recover.
- Gaps in data and our knowledge of the marine environment can make the ecological feasibility and success of any proposed marine biodiversity offset difficult to quantify or predict. Uncertainties and limitations of offsets should be clearly understood, defined and disclosed in project proposals and mitigation plans.
- Apply well-accepted ways to add contingency when calculating biodiversity offset requirements and designing offset strategies to account for risks (see Box 23).

Box 23: Addressing risk and uncertainty

Risk and uncertainty can arise as a result of risks relating to, for example, social, political, ecological, institutional, financial aspects. A number of approaches have been developed to take such uncertainties and risks into account. Examples include:

- Investment in the establishment of **robust baselines** (Principle 8), field work and research can help to address uncertainty associated with limitations in data or knowledge.
- Requiring the implementation of offsets and **delivery of intended conservation outcomes *before* impacts** are allowed to occur (e.g. conservation banking schemes in United States).
- Design offsets to be **outcome rather than activity focussed** – i.e. if activities designed to support the recovery of a population of reef fish fail, alternative strategies will need to be employed to achieve intended outcomes.
- Progressing a **larger and more varied portfolio of offset sites and actions** as insurance against offset failure.
- Adopt an **adaptive management** approach. This is important in uncertain and data-poor marine environments. As more information is made available, offset actions and management measures must allow for change in order to achieve intended conservation outcomes.
- Use of **defensible multipliers,** that serve to increase the basic size of the offset, are commonly applied to deal with uncertainty in the ecological system, offset implementation and time delays associated with offset delivery. Expert and local stakeholder participation is important when determining the applicability and size of multipliers. Multipliers cannot address all types of risk and it is good practice to avoid using multipliers to address uncertainty in the technical ability of an offset to deliver intended conservation outcomes.
- Use of systematic conservation planning tools, such as RobOff[255,256], that can help to account for uncertainty and time-lags between biodiversity loss and predicted offset gains by comparing a range of possible scenarios to determine the optimal allocation of resources to ensure that offsetting gains are sufficient to balance development losses.

Further information and guidance for identifying and addressing risk and uncertainty is available[245,255,257,258].

Principle 10: Share information and data

- The marine oil and gas sector has an important role to play in improving regional knowledge and mapping of the marine environment. Making information and data from BES baseline studies publicly available can help to advance understanding of the marine environment, support seascape level approaches and, in turn, improve offset design and feasibility.
- Practical experience and lesson sharing on offset application in diverse contexts is needed, particularly in marine contexts given the relative infancy of marine offsets. It is through the sharing of successes and failures that advances in good marine offset policy and practice will be made.

Principle 11: Limits to offsets

Not all residual impacts can be offset. There are ecological, scientific and stakeholder defined limits to what can be offset. This may reflect the importance[ii] or sensitivity of biodiversity values present at the site, high risk of permanent and irreplaceable loss of those values if an offset is unsuccessful, the lack of offset options in the land or seascape, and/or high risk of offset failure.

Credit: Pippa Howard

Guidance for determining limits to offsets has been developed[259,260,261,262] and typically involves consideration of biodiversity values in terms of their vulnerability and irreplaceability (or uniqueness), and the likelihood of offset success. In general, the more vulnerable and/or irreplaceable the biodiversity, the greater the risk of loss associated with project impacts and the less likely that an offset can be achieved. However, even for more common habitats, some areas have naturally high values for reasons of ecological integrity, representativeness, condition, the proportion of a population existing there, the limits of a species' range, or because of a combination of factors[259]. The concepts of vulnerability and irreplaceability are also relevant when determining limits to offsets designed to counteract adverse impacts on ecosystem services[263,264].

Determining the likelihood of offset success should take into account the magnitude of the impact, availability of offset options in the land or seascape, and feasibility of delivering the offset and securing outcomes over the long-term. Limits to offsets must be properly evaluated and the acceptability of risks determined early on, in reference to existing guidance and in consultation with experts and stakeholders[259].

Principle 12: Offsets deliver outcomes for biodiversity that are additional

Offsets must be additional to any other (ongoing or planned) conservation measures. They should ensure additional outcomes for biodiversity conservation, in that they are due to the offset activities and would not have occurred without them. To measure

ii Importance may relate to the contribution of biodiversity values towards the function and integrity of affected ecosystem/s, persistence of biological diversity, maintenance of ecosystem service provision, and/or importance to society (e.g. intrinsic values or cultural significance).

additionality, offset gains need to be assessed against appropriate baselines and may take account of counterfactuals – i.e. background biodiversity loss. Opportunities for additionality in marine offsets may be high, owing to the range and severity of threats and limited protection for marine ecosystems. However, risks of 'leakage', whereby an offset displaces adverse impacts to another location, may be high in marine systems due to greater connectivity and scales of movement. Leakage risks should be determined and reduced wherever possible in offset design and implementation.

Principle 13: Offsets support long-term durable outcomes

Offsets should be designed to be long-lasting and durable. At a minimum, offsets should be effective for at least the duration of the direct, indirect and cumulative impacts caused by the project. Moreover, the full consequences of impacts for marine species and ecosystems will often be unknown given limitations in our understanding of marine biodiversity sensitivities, interaction and flow effects, and tipping points or thresholds beyond which rates of decline or degradation may accelerate and/or be irreversible[265]. With limited legal protections outside a country's exclusive economic zones, alternative implementation models will need to be investigated in close collaboration with government and civil society stakeholders to provide long-term protection of offset sites and outcomes[266]. Success in achieving long-term durable outcomes will be affected by a range of factors (e.g. relating technical, ecological, social, political, financial and legal aspects).

Principle 14: Ecological equivalence between biodiversity losses and gains is maximised

International best practice and many national offset policies emphasise the need to ensure ecological equivalence between the conservation gains resulting from offset actions and losses from residual impacts[267]. Ecological equivalence looks to ensure the biodiversity targetted by an offset is 'like for like' with the impacted biodiversity it is seeking to compensate. Ecological equivalence has a number of dimensions:

- Type (i.e. of species, community, habitat, ecosystem, function or service).
- Condition (or quality) describes the intactness, health or degree of functionality of ecosystems (see Box 24).
- Amount (number or extent) of losses and gains, as measured or estimated.

Box 24: Measurement and metrics

The metrics used to quantify BES and determine the equivalence of losses and gains vary but include:

- Species population metrics (e.g. coral reef fish species counts; modelled population estimates of whale sharks; photo-identification of manta rays; turtle population numbers from nesting beach counts and aerial surveys etc.).
- Habitat or vegetation type and area. The use of habitat type and area is commonly used alongside other metrics (e.g. condition). Use of habitat area alone is limiting - just because an area is the equivalent size and habitat does not mean it will perform the same function in the land or seascape. Area and habitat based metrics are not sufficient for capturing losses and gains in ecosystem services.
- Condition or health metrics are therefore incredibly important in determining equivalence of losses and gains. In the context of marine realm these may involve complex, aggregated measures that incorporate multiple indicators of ecosystem health. For example, coral health may incorporate measures of coral cover, biodiversity, coral recruits, coral disease and crown of thorns starfish numbers at a selection of reefs[245]. Condition or health metrics are best co-developed and agreed with relevant stakeholders and experts.
- Metrics that take into account the ecological patterns and processes that maintain healthy ecosystem function which in turn enable the maintenance of ecosystem services.
- Ecosystem service supply metrics that measure, for example, the quantity, quality and/or reliability of ecosystem service supply; valuation methods (monetary and non-monetary) that determine the relative 'value' or importance of the service/s for different beneficiaries; and measures of loss and gain of ecosystem service benefits over space and time (e.g. months of lost access to fishing areas) are metrics commonly used to measure ecosystem services. It is important that both the supply of, and demand for, ecosystem services, and the relationship between the two, are taken into consideration when determining losses and gains and equivalence.

Further guidance on measurements and metrics for offsets is available[226,257,264,268] (see also resources listed in Appendix 4).

Temporal and spatial aspects require careful consideration. For example:

- Time-lags between losses and gains may put the persistence or recovery of species and ecosystems at risk. Offsets should, wherever possible, be implemented (or under implementation) and deliver conservation outcomes *before* impacts occur.
- Several small, fragmented patches of seagrass habitat will not be equivalent to one large, well connected seagrass meadow of the same total area. It is therefore necessary to consider the wider context and the extent of connectivity or fragmentation when scoping offset options in the land and seascape.
- The distance between the impact and offset sites presents opportunities and constraints for offsetting impacts to marine ecosystems. Offset areas located close to impact sites may be more likely to share similar species and habitats, perform similar functional roles and provide ecosystem services to the same beneficiaries (see Box 22). However, the dynamic and highly connected nature of marine systems may mean that the most effective strategy to compensate for project impacts is to address other threats some distance from the impact site (see Box 29). Policies that promote on- or near-site offsets, without consideration to alternative opportunities that may provide greater connectivity or feasibility of success, may lead to fragmented restoration sites with high failure rates[245].

For offsets designed to counteract adverse impacts for ecosystem services, it will be essential to consider ecosystem service beneficiaries and the degree to which those adversely impacted from the development project will benefit from ecosystem services maintained, restored or enhanced through offset activities.

In practice, it is very difficult (if not impossible) to achieve absolute ecological equivalency (or 'like-for-like') in terms of composition, structure, function and services. This is particularly the case in the marine environment[269]. Thus, there will be some degree of exchange or trade. Whilst the rules governing these exchanges and associated limits will vary in different jurisdictions, it is important that assessments of ecological equivalence are robust and defensible[267]. However, in general offsets should provide conservation benefits similar to those lost due to the project, or provide benefits that better meet conservation priorities, also referred to as 'like-for-better' or trading up'[270,271].

Owing to challenges in identifying ecologically equivalent or 'like-for-like' options in the marine environment and uncertainties over intended outcomes, a pragmatic approach is being recommended in some jurisdictions. In such cases, a range of offset options are being proposed to maximise marine conservation outcomes, with the goal of ensuring the long-term net improvement of coastal and marine environments, improved ecosystem resilience, and ultimately a net biodiversity gain.

6.4. Key steps in a good biodiversity offset process

The process of planning and implementing good practice biodiversity offsets is covered extensively elsewhere. Here, the stages in the offset planning process are illustrated in Figure 16 (adapted from BBOP Offset Design Handbook[226]) and several of the main steps are summarised. The principles outlined above apply throughout. Readers are referred to existing resources[226,227,228,264,268,272] for further detail and guidance.

Key overarching steps in the offset planning and implementation process are as follows:

Determine offset requirements based on residual adverse impacts

To know what should or could be offset, it is first necessary to estimate anticipated biodiversity losses resulting from the oil and gas project (including those resulting from direct, indirect and cumulative impacts), taking account of expected gains from avoidance, minimisation and restoration measures. Choice of methods and metrics for calculating losses (from impacts) and gains (from mitigations) and quantifying residual losses will need to be guided by international standards, national or state legislation and/or company commitments. Guidance is available to support the estimation of losses and gains and determining residual losses[227,267,273].

Offset scoping and design

Offset scoping is the assessment and prioritisation of different areas within the land and seascape that have the potential to contribute to achieving offset requirements (see Figures 15 and 16). This involves assessing how potential offset receiving areas[iii] contribute to offset targets for impacted BES components whilst also considering their contribution to seascape-level goals and minimising associated costs. In any given land or seascape there will often be multiple options for meeting offset requirements, including several spatial networks and a range of conservation actions with potential to meet no net loss or net gain requirements.

iii Offset receiving areas: locations in the land or seascape that theoretically could meet site specific offset requirements

Full consideration of all available options and associated opportunities and constraints is critical in ascertaining the 'optimal' offset or network of offsets and in building the evidence-base to support it.

A systematic planning approach[274] and the use of conservation planning tools can support a transparent, objective and repeatable offset scoping process; helping to address questions of 'where' in the land or seascape offsets could be located[275] and 'what to do'[255]. Figure 16 illustrates the sequence of steps in a systematic offset scoping process designed to identify offset options within the land or seascape. Key to this approach is the use of scenarios when analysing different offset options. Scenarios can be developed to take account of different ecological, social, political or financial priorities and constraints and in this way effectively deal with some of the complexity found in real land and seascapes and allow for the analysis of trade-offs. Through this approach potential offset receiving areas can be prioritised from the perspecitive of biodiversity, ecosystem services, landscape and seascape goals, cost efficiency, etc. Priority offset receiving areas can then be further investigated and evaluated, in close consultation with local stakeholders, authorities and experts, to select the optimal offset network and activities taking into account the full range of risks and uncertainties.

Throughout the offset scoping and design process each of the principles outlined above (Section 6.3) should be applied.

Figure 15: Offset options in the land and seascape to compensate for residual impacts of project development. Conceptual diagram illustrating development project including associated infrastructure and activities (left) and offset options in the land and seascape to compensate for remaining residual impacts after all avoidance, minimisation and restoration measures have been taken into account (right).

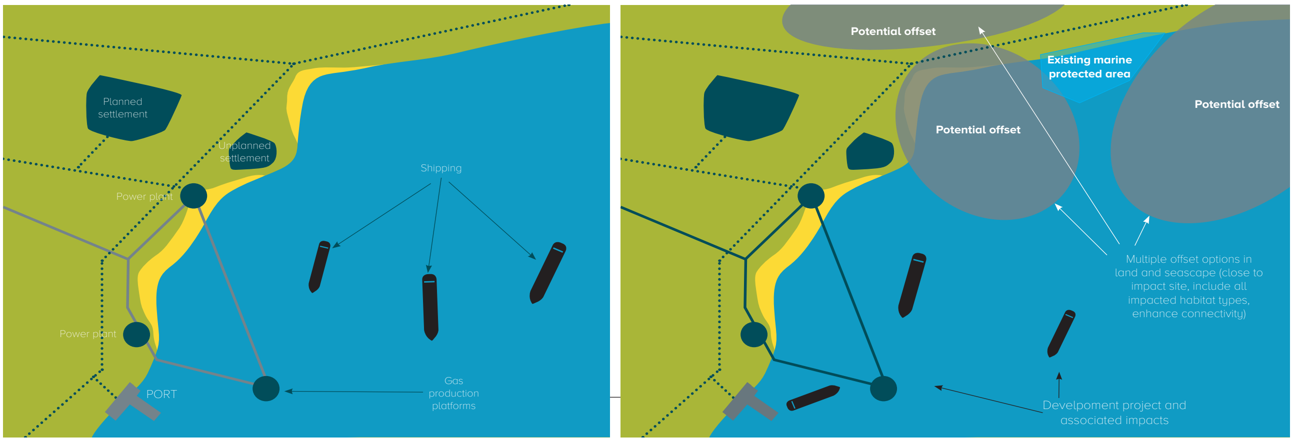
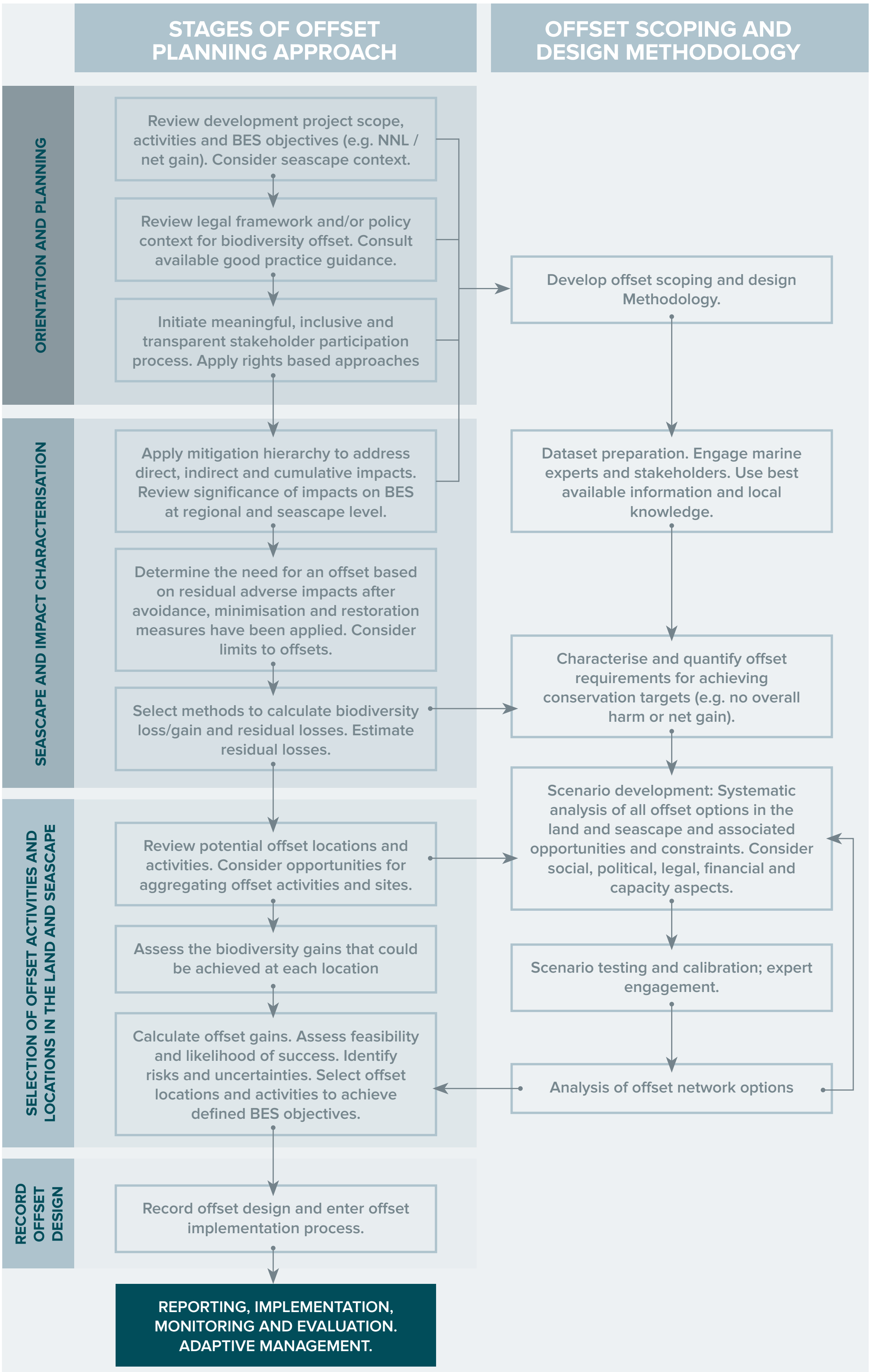


Figure 16: Biodiversity offset planning process and the importance of systematic offset scoping. The overarching offset planning approach (adapted from the BBOP Offset Design Handbook[226]) is illustrated (left) along with complementary steps involved in the offset scoping process (right).



Offset implementation

At its core, a biodiversity offset is a conservation project (an integrated set of conservation activities), even though it is linked to one or more development projects that adversely affect BES[226]. It involves:

- specific activities and inputs (see Section 6.5, below);
- clearly defined institutional roles and responsibilities (e.g. of government agencies, community groups, non-governmental organisations, private firms etc.);
- clearly defined, agreed and documented timeframes;
- comprehensive budgeting that covers up-front, long-term recurrent and contingency costs;
- funding – at a minimum payment that fully finances the offset plan should be secured as part of the oil and gas project's investment costs *before* the impact is allowed to occur, with funds being transferred to an appropriate vehicle before the project is under way;
- monitoring and evaluation plan.

Good conservation outcomes from biodiversity offsets will be determined by numerous factors that affect the success of the offset over the long term. These factors include, among others, economic and financial safeguards and incentives, the strength and degree of implementation of legislation, institutional capacity, political and stakeholder support, coordination and collaboration among relevant parties (see Box 25), data availability and access to technical expertise. It is therefore necessary to balance scientific rigour with practical realities (and implementation opportunities and constraints) without jeopardising what offsets are intended to achieve[276].

Guidance to support the implementation of biodiversity offsets is available[272]. The development and implementation of marine offsets must also be informed by the experience and resources developed by the marine BES conservation sector (see Appendix 5).

Box 25: Partnership and collaboration

The successful development and implementation of biodiversity offsets requires effective communication and coordination among many parties including local and national government, community-based organisations, non-governmental organisations, local stakeholders, companies, research institutions, marine BES experts etc. Partnerships (e.g. with community groups, universities and/or conservation organisations) and a collaborative approach (e.g. with other companies operating in the same seascape) are needed.

Monitoring and evaluation:

Biodiversity offsets require significant investment in the monitoring of implementation and, crucially, outcomes. Refer to recommended guidance[272] (and references therein), Section 7 and Appendix 5 for further discussion.

Credit: JABRUSON

6.5. Options and activities for offsetting impacts in marine ecosystems

Restoration offsets

Positive management interventions that aim to restore or rehabilitate a degraded habitat or ecosystem and/or support the recovery of a threatened population[226] might involve one or a number of the below approaches:

- manipulating the physical, chemical, or biological characteristics of a degraded site to enhance natural functions or species communities in an existing habitat. For example:
  - employing measures such as benthic sediment stabilisation which help seagrass to re-establish[245]);
  - transplanting mangrove or seagrass (see Box 26);
  - Removal of sea urchins from rocks and kelp to reduce grazing pressure to allow kelp recovery[269];
- conserving or maintaining the health of one marine habitat type (e.g. mangroves and their role as a fish nursery) in order to restore the key ecological processes (e.g. herbivory – certain fish species eat algae in corals) necessary for the restoration of adjacent habitat (e.g. coral reefs in which algae can outcompete corals for space after a disturbance event)[242];
- addressing barriers to the movement of organisms within and between ecosystems to enable recovery of species;
- reducing threats to highly interactive or keystone species to enable population recovery and support the restoration of key ecosystem functions;
- management of diffuse impacts (e.g. poor water quality) which involves undertaking actions (e.g. restoring riparian vegetation) to improve water quality upstream of the impact site and, in turn, support the recovery of target habitats, species or processes (see Box 29)[213];
- manipulating the physical, chemical, or biological characteristics of a site to develop a habitat that did not previously exist. For example:
  - providing suitable substrate to promote coral settlement and recruitment (see Box 27);
  - creating artificial islands in marine areas to form new habitat, including seabird and seal habitat[269].

See also Section 5 on restoration in marine ecosystems.

Averted loss offsets

Averted loss offsets aim to achieve biodiversity gains by removing or reducing existing or anticipated threats to habitats and species (independent of project impacts) within the land or seascape. This may involve:

- supporting the creation, expansion or buffering of marine protected area/s (see Box 28);
- actions to maintain connectivity between marine protected areas which is important for maintaining diversity, fish stocks, ecosystem function and resilience;
- managing threats to important ecological corridors (e.g. dispersal pathways; migration routes etc);
- managing threats to high priority species (e.g. protection of seabird populations through measures such as the eradication of invasive mammal predators[269]);
- supporting the establishment of controlled-fishing zones, or development of local sustainable harvesting systems[277];
- working with communities to improve marine resource management;
- managing diffuse or distant threats (e.g. reducing agrochemical run-off from agricultural land uses upstream);
- changing fishing practices to reduce bycatch of cetaceans, sea birds and marine turtles (e.g. funding the supply of more selective fishing gear types to fishermen and/or training fishermen to use these gear types[269]); and
- upgrading the protection of threatened species through changes to policy e.g. promote legislature that stipulates it is illegal to harvest marine turtle eggs.

Contribution to the strengthening of existing, legally recognised protected areas for biodiversity conservation, whilst permitted under certain conditions in some jurisdictions, is generally considered unacceptable for offsets where there are existing commitments to improving or maintaining the system[278,279].

For averted loss offsets to be defensible, it must be shown that ongoing or impending threats are imminent and will have significant adverse impacts on biodiversity. Risks of leakage (whereby the offset displaces adverse impacts elsewhere) must be fully evaluated and mitigated[280].

Aggregated offsets

Aggregated offsets refer to a system in which biodiversity offsets arising from more than one development project are planned and implemented in a systematic and coordinated manner. This can mean, for example[227]:

- planning one or more relatively large offset sites that would compensate for the residual impacts of multiple development projects;
- pre-selecting offset areas (e.g. areas identified as priorities in seascape conservation plans) to facilitate support from development project sponsors;
- promoting the use of biodiversity offsets through some type of national or sub-national government planning framework[281,282].

Whereas project by project offsets can contribute to disparate and fragmented collection of offset sites[283], strategically aggregating offset sites can be more effective in achieving overall biodiversity conservation outcomes by increasing connectivity, preventing future habitat fragmentation, creating large contiguous sites and building ecosystem resilience. Implementation of offsets in a few, larger areas can also be more cost effective as it consolidates capital expenses, management and monitoring. Given inherent characteristics of marine ecosystems with respect to flows, complexity and scale (see Section 3 and 6.2) and the critical need to deal with cumulative and diffuse impacts on marine biodiversity, aggregated offsets may prove a valuable approach to help counteract residual impacts of development on marine systems.

Other measures that may considered in some jurisdictions

Indirect offset measures (also referred to as secondary or surrogate measures) such as research, education or investment in an environmental fund supporting a range of conservation activities (not necessarily linked to impacts of the development project) may be legally applicable or recommended as part of an overall offset strategy where they complement and enhance the primary offset activity and add materially to environmental knowledge, research, management or protection (e.g. in Australia[284,285]). With regards marine offsets, there has been call in some parts for greater consideration to be given to the value that targeted, independent research programs can provide as part of an offset strategy[236]. Currently, however, such interventions are generally not considered acceptable as offsets because outcomes are often hard to measure and may not relate in a meaningful way to residual impacts of project development.

6.6. Case studies

Case studies outlining examples of biodiversity offsets projects undertaken in marine ecosystems are provided below (see Boxes 26 – 29). Publicly available marine offset projects implemented are limited in number and mainly in countries with mandatory offsetting requirements built into project approvals; notably in Australia. Studies which assess and document the efficacy of marine offsets are also considered to be 'scarce and patchy' especially when compared to examples from freshwater and terrestrial ecosystems[286]. Case studies presented below are based on real examples of marine offsets that have been designed with reference to specific legislative frameworks and are publicly available. These case studies provide useful insight and learning that can help to inform development of good practice marine offsets elsewhere.

Box 26: Seagrass restoration offset, Western Australia

The Albany Port Expansion Project involves the dredging of approximately 12 million cubic metres (Mm^3) of sediment in the Port of Albany, Western Australia. The project was required in order to widen and deepen the existing shipping channel into Princess Royal Harbour and to extend the shipping channel into King George Sound[287]. Approval was granted by the Western Australian Minister for the Environment in 2010, subject to several conditions including the design and implementation of a Seagrass Rehabilitation and Monitoring Management Plan[288].

Historic loss of seagrass had been reported in Princess Royal Harbour. Between 1962, when the seagrass meadows were considered to be in pristine condition, and 1984, 66% of the seagrass meadows were lost and further losses were reported in 1988[289]. These historic losses were linked to deteriorating water quality in the harbour, largely due to disposal of waste water from industry including woollen mills, fertiliser factories, food processing and sewage treatment works. In response, water quality improvements which reduced excessive nutrient loads and macro-algal accumulations proved successful at halting the decline and increasing the seagrass extent[290].

The Albany Port Expansion Project has the potential to adversely impact seagrass habitat as a result of direct removal or burial of sea grass and the indirect loss of benthic primary producers such as seagrass due to increases in turbidity and reductions in light availability. Studies undertaken in the area did demonstrate that seagrasses in Princess Royal Harbour and King George Sound are known to be capable of withstanding several months of shading[289]. Proposed dredging activities were required by the West Australian Environmental Protection Authority (EPA) to minimise sedimentation and turbidity i.e. 'undertaken in a manner that does not cause any overflow of turbid water into the environment from the dredge vessel'[288].

Other mitigation measures included temporal avoidance of dredging disturbance in the shipping channel between 1 November and 28 February in any year. Furthermore, where monitoring indicated that seagrass health was being adversely impacted the proponent would be required to immediately cease and relocate dredging activities. Residual impacts following mitigation measures were predicted to include the permanent loss of seagrass meadows at Princess Royal Harbour (approximately 0.8 ha) and possible losses within King George Sound (approximately 16.6 ha[i] [291]).

As of 2015, dredging had not commenced and the project was in the pre-construction phase with construction placed on hold. However, in line with approval conditions seagrass rehabilitation required to offset residual impacts commenced in conjunction with a seagrass monitoring program in 2012. Prior to the commencement of dredging and reclamation the proponent was required to rehabilitate of a minimum of 1 ha of seagrass in Princess Royal Harbour using seagrass donor material from the area impacted by port expansion. A planting density that achieves 75% average cover was expected within 10 years of planting. The species to be used in seagrass rehabilitation included ***Posidonia sinuosa*** and ***Posidonia australis***.

Results from the third year of seagrass monitoring (1st May 2014 and 30th April 2015) undertaken by Oceanica Consulting Pty Ltd., indicated that seagrass sprig survival was on average 78% which exceeded the performance criteria of 60%. Subplots in the rehabilitation area which showed lower seagrass sprig survival rates were adversely impacted by bioturbation by naturally occurring marine worms. Based on the findings of the sea grass monitoring it was stated that 'the seagrass rehabilitation is on target to achieve the approval target of 75% coverage in 10 years[287].

i Permanent losses of seagrass in King George Sound, over a predetermined threshold will also be offset as required in consultation with relevant statutory bodies. However due to project delays were not available at the time of writing.

Box 27: Biogenic reef offset, Western Australia

Land reclamation for the expansion of an ore stockyard within the Dampier Harbour, Western Australia resulted in the loss of nearshore coral communities. The landward expansion of the stockyard was constrained due to unfavourable steep rocky ground and an existing rail line. As such, avoidance was not deemed to be possible. The residual impact was the loss of nearshore coral communities and was required to be offset. In December 2006, a 0.6 ha artificial reef with suitable substrate for coral settlement was constructed using local rock boulders (1-2 m diameter) and recycled concrete sleepers (2.5 x 0.7 x 0.5 m). The reef was located approximately 200 m from shore on sand substrate at a depth of approximately 6.5 m at mean sea level[292].

Regular monitoring was undertaken at six month intervals between August 2007 and February 2012 to record site conditions and test whether the target of at least 10% coral cover within 10 years would be achieved. The site experienced relatively harsh environmental conditions because of both natural and anthropogenic factors including annual water temperature between 18-32°C, intermittent high turbidity (occasionally exceeding 50 nephelometric turbidity units), cyclones and nearby ship movement[292].

Monitoring programs demonstrated that some coral settlement occurred on the artificial substrate within a few months. Mean coral cover then rose slowly in the next couple of years, before rapidly increasing after five years, reaching an estimated 2.3 ± 0.7 SE % in the final survey[292]. As a point of reference, mean live coral cover of approximately 30-35% was documented on an established natural reef site (100 m from the artificial reef) between 2006 and 2010. The current coral community composition on the artificial reef also differed markedly from that of the nearby natural reef. This was due to different stages of development i.e. early developmental stage with high abundance of early coloniser coral species. Given the artificial and natural reef are structurally similar the coral community and diversity has the potential over time to eventually approach that of nearby natural reef. However, multiple mechanisms were noted to have the ability to constrain the development of the artificial reef including disturbances such as cyclones, high or low water temperature (a bleaching event occurred in 2008) and high turbidity/sedimentation events and biological mechanisms including disease, predation and competition.

Other studies from the United Arab Emirates on two large, mature artificial reefs (i.e. breakwaters) illustrated that even after several decades artificial reefs might still not be considered as replacements for natural coral and fish communities when compared to nearby natural habitats[293]. Monitoring did demonstrate that coral cover on artificial reefs was in some cases higher than natural habitats (likely due to elevation above the sandy substratum) and these reefs can support diverse and abundant coral and fish communities. However, coral diversity and composition were lower than natural patches possibly due to difference in habitat characteristics such as structural material, orientation and complexity[293]. Therefore, artificial reef when designed to offset the loss of natural coral ecosystems, should consider and attempt to replicate the structure, substrate, aspect (i.e. seaward or landward), depth, and surface orientation (horizontal or vertical) of the impacted coral ecosystem.

Box 28: Marine offsets in the Great Barrier Reef Marine Park - Queensland, Australia

Five major projects which involved marine offsets for the Great Barrier Reef World Heritage Area (GBRWHA) were approved between October 2010 and March 2013[266]. These projects occurred within the Great Barrier Reef Marine Park along the coast of Queensland, Australia. Several of these projects were located offshore from the city of Gladstone, on Curtis Island. One project, Queensland Gas Corporation (QGC)'s Queensland Curtis liquefied natural gas (LNG) project was approved on 22 October 2010 subject to a number of conditions, including those relating to biodiversity offsets. In addition, this project was one of five projects considered during the 2014 Australian Senate inquiry into biodiversity offsetting.

QGC's project infrastructure on Curtis Island included a LNG facility where the gas is converted to LNG for export to global markets, a gas pipeline to transport gas from the mainland to the processing plant, marine facilities including a construction dock and material offload facilities, and increased shipping activities associated with construction and LNG shipments. The project was expected to generate significant economic benefits to the region, including an estimated 4,000 direct jobs (at the peak of construction) and approximately 1,000 permanent positions during operation[294].

Intertidal and marine facilities overlapped with marine habitats comprising marine couch grassland, saltpans and samphire herbland (17 ha), seagrass (10 ha), and mangroves (6 ha)[134]. These areas provided habitat for a range of marine and migratory species such as shore birds (27 ha) and the threatened water mouse (***Xeromys myoides***) (5 ha). Significant impacts associated with the project included the direct loss of marine habitats which support threatened and migratory species; loss of World Heritage and National Heritage values in the Great Barrier Reef World Heritage Area; and indirect pressures to marine species and habitat from shipping, dredging and increased workforce[236].

The QGC project received federal and state approval prior to designing detailed offset strategies and management plans. The UNESCO Monitoring Mission has criticised the decision to allow the projects to proceed before the offset design and arrangements were in place[295]. Furthermore, delays were experienced in securing suitable offsets and offset areas when findings of the Australian senate inquiry were published in June 2014[236]. However, delays could be expected given the scale of the project, complexity of issues and the need to secure land tenure. Three LNG projects (including Queensland Curtis LNG Project, the Santos GLNG Project and the Australia Pacific LNG Project) collaboratively delivered an offset strategy which included the acquisition and management of former agricultural land and upgrade of existing protected areas within 15 km of the project footprint in the Great Barrier Reef World Heritage Area. Ecological assessments demonstrated that the acquired freehold and leasehold lots contained approximately 307 ha of remnant marine habitat including marine couch grassland, saltpans and samphire herbland, mangrove and seagrass, 311 ha of habitat suitable for shorebirds and 502 ha habitat suitable for water mouse[134]. These area values were significantly larger than the marine footprints of the LNG proponents including QGC and were deemed to fulfil both Australian and sub-national government offset requirements for marine impacts (as well as terrestrial).

The control over the acquired freehold and leasehold lots (i.e. the offset area) including subsequent management was surrendered to the sub-national government. The LNG proponents will contribute significant funds towards the management of the secured offset area. The offset management measures include the removal of approximately 1,500 domestic cattle (reduce trampling threat and promote nature regeneration), active control of other pest species including feral pigs and pigs (reduce predation of native species) and pest plant species, removal of agricultural infrastructure including unnecessary fencing (reduce barriers to fauna movement) and fuel storage facilities (avoid contamination to surrounding waterways), appropriate management of the fire regime and passive regeneration of cleared areas[134]. These land-based management measures i.e. the removal of threatening processes are expected to result in progressive improvement to the condition of the marine habitats which are required to be offset and The habitat found within the offset area have experienced adverse impacts from grazing under previous land management regimes. The removal of cattle grazing and associated erosion and nutrient runoff is also likely to improve the water quality of the surrounding waterways of the Great Barrier Reef Marine Park. In addition, the purchase and protection of the intertidal property will prevent future proponents from developing these areas e.g. greenfield port construction.

Other project offsets or other compensatory measures include:

- contribution of $266,894 to the migratory shorebird research program in order to offset the unavoidable impacts on listed migratory birds[134].
- development of a long term turtle management plan comprising monitoring of turtles in the Gladstone Harbour region
- cash payment of $200,000 per annum plus $100,000 per annum per operating LNG processing facility to support field operations within the Great Barrier Reef Marine Park[236].

Box 29: Targeting diffuse land–based threats: Offsetting marine impacts on land in north Queensland, Australia

The Abbot Point coal terminal expansion involves the capital dredging of approximately 3 million cubic metres at the existing Port of Abbot Point, construction of additional coal loading jetties and the disposal of the dredged material (including options at sea)[236]. Project impacts to the marine environment would include the direct removal of sea grass meadows and the alteration of water quality conditions i.e. increase in turbidity.

This case study demonstrates the potential to utilise an understanding of a seascape and/or upstream catchment to offset unavoidable residual impacts on site with management interventions targeting diffuse impacts in geographically distant areas. For example, it has been suggested that impact on a seagrass ecosystem could theoretically be offset by improving water quality parameters in an upstream location[213]. Furthermore, it might be inappropriate to attempt to actively restore a marine ecosystem that is exposed to non-project related constraints such as elevated nutrient levels, turbidity and low light conditions.

In order to address the loss of seagrass and potential loss resulting from the dredge plume extent, the proponent suggested investment in sediment reduction options in the Great Barrier Reef catchment. This involved undertaking land based management interventions to reduce the load of fine sediments entering the marine environment from the Burdekin and Don catchments. Interventions might include improved land management practices, exclusion fencing of areas prone to erosion such as gullies, removal of hard hoofed feral animals such as feral pigs and replanting native riparian vegetation at high risk areas. The required reduction was proposed as 150% of the total amount of fine sediments, potentially available for re-suspension into the marine environment from the dredging and disposal activities.

Note: Whilst theoretically possible it has been argued that such a significant undertaking (estimated by some stakeholders at around 1.62 million tonnes of fine sediments required to be offset) might not be practically possible given the limited achievements of government led programmes designed to improve water quality in the GBRMP[236]. Other stakeholders had concerns that alternative designs and options which avoided the need for offshore disposal were not fully considered. Subsequently the proponent has revised the dredging and disposal programmes and is likely to dispose of dredge material on disused terrestrial port land. This has reduced the extent of adverse impacts to marine habitats and instead impacts and offset requirements will largely be shifted to terrestrial and wetland habitats. However, the offset strategy shall still 'contribute to catchment management measures that improve coastal water quality'[296].

7 Monitoring and evaluation

A number of texts provide advice on environmental monitoring for the oil and gas industry in the marine environment[i]. The intention of this section is not to replicate this advice, but rather to establish the specific considerations for monitoring and evaluation (M&E) of biodiversity and ecosystem services. A summary of the key elements of M&E is presented first. Then, consideration is given to identifying M&E objectives and indicators, and planning a monitoring programme. Finally, methods of assessment for each of biodiversity and ecosystem services are considered, giving examples of what to monitor

i Examples of documents including advice on environmental monitoring in the marine environment include: OGP (2012) Offshore environmental monitoring for the oil & gas industry. International Association of Oil and Gas Producers; WBG (2015) Environmental, Health and Safety Guidelines Offshore Oil and Gas Development. World Bank Group, Washington DC.

M&E helps improve a project's performance and achieve results[297]. M&E involves the assessment of a project's progress against pre-defined targets to ensure the activities are on track in terms of timeline, activities and delivery. It also involves the assessment of project activities against higher order objectives to determine whether the desired outcomes are being achieved.

The two components are defined as follows[298]:

Monitoring is a continuing function that aims primarily to provide project stakeholders with early indications of progress towards defined goals. Monitoring helps companies track achievements by a regular collection of information to assist timely decision making, ensure accountability, and provide the basis for evaluation.

Evaluation is the systematic and objective assessment of a project, including its design, implementation and results. The aim is to determine the relevance and fulfilment of objectives, development efficiency, effectiveness, impact, and sustainability. An evaluation should enable the identification of lessons learned for future projects.

Monitoring and evaluation are closely linked: information collected through monitoring is an important source of data used in evaluation. Monitoring tells us whether an activity is on track to achieve its intended objectives, whereas evaluation tells us whether the project as a whole is on the right track[299].

A formalised system of M&E enables the measurement and monitoring of a company's impacts upon BES and assists the understanding, prediction, minimisation and prevention of negative impacts[300]; enhancement of positive impacts; management of activities; and the development, monitoring and refinement of corporate policy and expected best practice standards[301].

M&E enables a company and other stakeholder groups to track compliance with national and international laws and performance against corporate or lender standards and industry good practice. Further, the information collected can be instrumental in communicating BES performance both internally and to external stakeholders. Such communications and the demonstration of a clear BES evidence base are likely to be instrumental in companies accessing resources[300], maintaining good relations with communities and attaining their social licence to operate[301].

M&E should be a continuous process throughout the life of a project, recognising that the focus of the M&E will be different for each phase of the project cycle to reflect the different impacts and priorities. For example, during seismic surveys a focus of M&E will be pelagic species including fish and marine mammals likely to be affected by noise. During project development and operations, the focus is likely to shift to pelagic and benthic habitats impacted by rigs and subsea infrastructure. IOGP's e-SHRIMP[i] is a convenient system for identifying M&E needs at different stages of a project's cycle[300].

Box 30: IFIs and guidance on M&E

Lender standards do not prescribe which elements of BES an operation should monitor, due to the context-specific nature of different operations. Instead, they usually set out general requirements for monitoring. For example, IFC's PS6 states that for Critical Habitat "A robust, appropriately designed, and long-term biodiversity monitoring and evaluation program is integrated into the client's management program." Further details are provided in the Guidance Notes, which set out the following broad considerations for monitoring biodiversity:

- in-field monitoring of species and habitats, and monitoring of the effectiveness of mitigation measures;
- the need for a separate monitoring programme for any biodiversity offsetting;
- the desire for statistically defensible results; and
- the need to identify thresholds for key biodiversity, in conjunction with external experts, against which success will be measured.

In all cases, it is important to ensure that ecosystem function and persistence of BES is incorporated into the M&E programme.

7.1. Identifying M&E objectives

The purpose of an M&E programme is to measure progress against an operation's specified targets for BES.

i E-SHRIMP: Environmental, Social & Health Risk and Impact Management Process

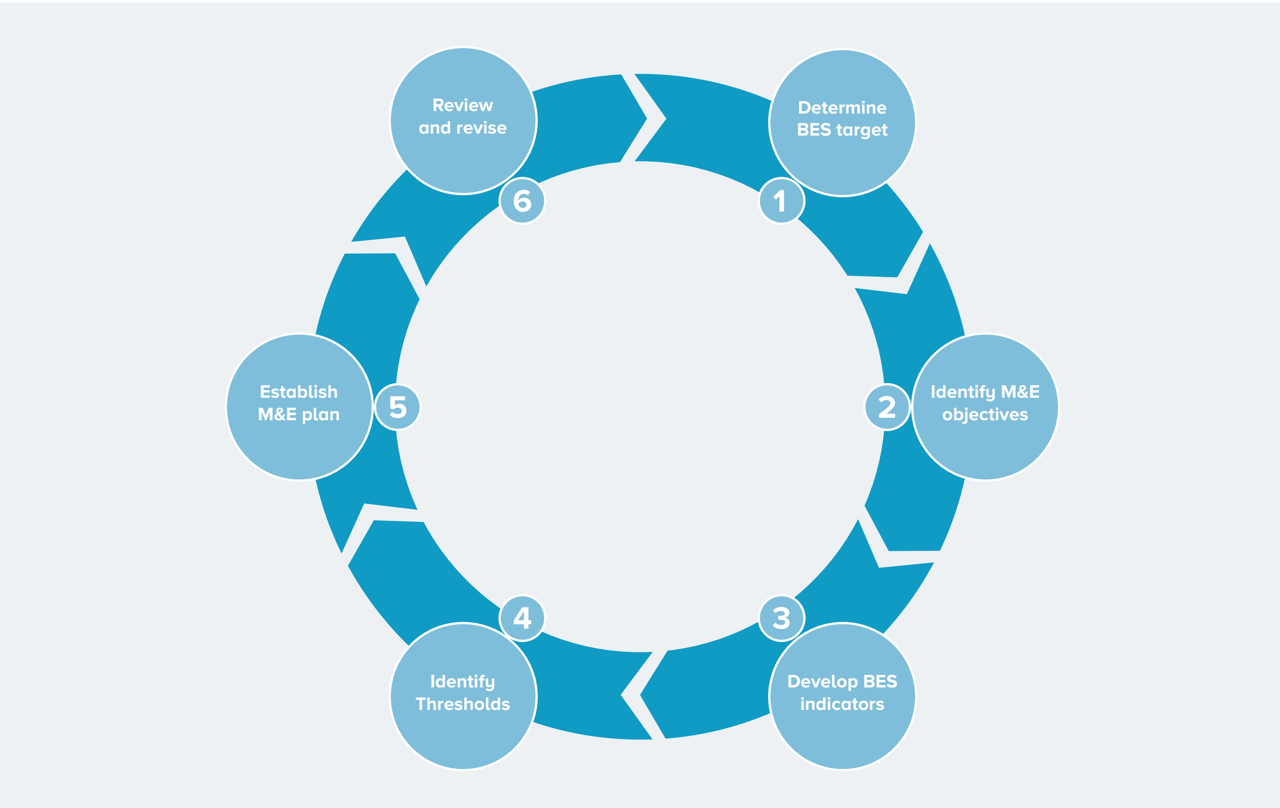
Monitoring requirements for BES are not usually specified in national legislation for the oil and gas industry[ii]. Similarly, IFI lender requirements and industry good practice do not specify what elements of BES should be monitored, as each operation is essentially unique (see Box 30). M&E requirements will vary depending on the size and complexity of the operation, and the social and environmental sensitivity of the surrounding area[300].

It is therefore necessary for oil and gas operations to develop an M&E programme tailored to their needs. The first step is to identify the high level targets for BES for the operation. These targets can take a number of forms: they may be high level and strategic, i.e. No Net Loss for biodiversity (a legislative requirement in 19 countries, and a lender standard for 32 IFIs). Equally, there may be need for a more specific, operational target to be fulfilled, such as ensuring the protection of a priority species, habitat or ecosystem services for a limited period of time, while a specific activity such as drilling or dredging is under way.

Whether working to a strategic and high level target or a more specific operational target, the approach to developing an M&E programme will be similar (see Figure 17).

Once the BES target/s have been identified, the next step is to identify objectives for M&E. Objectives should be measureable and achievable within specified time frames. Objectives should reflect BES of high value which is predicted to be impacted by operations, as identified through a structured risk assessment process[iii]. Using objectives that have been identified through a formal risk assessment process will ensure they are business relevant[301] and thus acceptable to corporate and operational management.

Figure 17. Iterative stages in the development of an M&E programme for an oil and gas operation



ii Legislation relating to the monitoring of BES is rare. A number of countries have defined biodiversity monitoring requirements relating to oil spills , or general environmental performance, but there are few cases where monitoring of biodiversity and ecosystem services is specified in national law.

iii The ESIA is an example of a structured risk assessment process. However, most oil and gas companies are will have their own operational risk assessment processes too.

7.2. Developing M&E indicators

Central to monitoring and evaluation plans is the identification of indicators which help track progress towards objectives. Indicators should help assess changes to the integrity of biodiversity, ecosystem functions, ecosystem services and the complex relationships between these within an ecosystem.

Indicators are quantitative or qualitative variables which are measurable and can demonstrate trends over time. M&E usually involves the collection of two kinds of indicators[303], the first for performance and the second for impact:

- **Performance indicators** measure the progress in securing project inputs and delivering project outputs against set targets

- **Project impact indicators** reveal trends towards, or away from, BES conservation targets

Both are essential in tracking the overall progress of the project. Performance indicators are usually based around the delivery of specific services, for example training sessions or construction of infrastructure. Impact indicators measure elements of biodiversity (e.g. species, habitats or ecological processes) or ecosystem services that are likely to be highly impacted by the project.

Impact indicators should be carefully selected to ensure they match the stated M&E objectives. Different types of impact indicators can be selected to represent the complexities of BES and ecosystem function and make the linkages between abiotic and biotic variables within an ecosystem. Direct indicators can quantify the ecosystem components through a number of means, e.g. area extents, yields, abundance or value variables. Relationship or process indicators can represent the underlying links and associations between the ecosystem component and other biodiversity, ecosystem function and ecosystem services within an ecosystem and across a seascape, e.g. predator-prey interactions or nutrient cycling. These relationship indicators add value to the direct indicators by helping to understand the potential impacts that may result as the underlying related ecosystem components change.

In certain cases, it may not be possible to directly measure the desired BES element, for example a rare or cryptic species, and a proxy may be required, such as area of habitat or availability of prey species. Such proxy indicators must be carefully selected to ensure they are biologically meaningful. Consultation with marine BES experts is recommended for the selection of all impact indicators, and especially proxies.

Occasionally, there may be an urgent requirement to identify an indicator so that operational activities can be modified to immediately reduce significant impacts[301]. In these cases, it may be necessary to consider in the short term an indicator that does not directly measure change in a biological system but rather measures change in an activity that, left unaltered, would lead to biodiversity impacts. Such a short-term, "indirect" indicator may enable activities to be quickly modified, while data are being acquired to develop a more appropriate long-term indicator based on the direct measurement of changes in the biological system[301].

Appropriate BES indicators should have the following characteristics[302]:

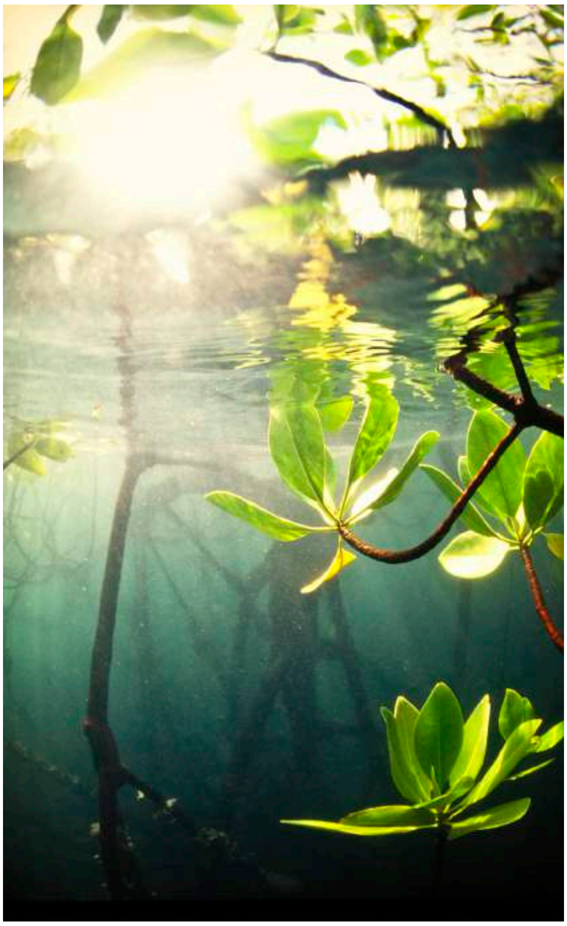
- **Relevant** to the activities of the project and objectives of the M&E program.
- **Understandable** and able to aid the interpretation of data, inform management plans and promote the communication of results.
- **Useable** for measuring progress and, in conjunction with thresholds, act as a preventative measure against negative change.
- **Scientifically sound,** equally informed by scientific information and able to be tested and measured.
- **Sensitive** to change**,** in that changes in responses or values can be detected.
- **Practical and affordable** to promote consistent application and ensure rigour in data over long periods of time

7.3. Identifying thresholds

The purpose of thresholds is to represent the difference between two or more different states or responses of an indicator. Thresholds help to predict and prevent changes to the value of key BES components which may cause degradation or loss of biodiversity, ecosystem function and ecosystem services.

BES indicators will usually be selected to track changes to a key biological trait such as population size for a species, area or quality for a habitat, interaction for a relationship or volume of offtake for a provisioning ES. For many indicators it is possible to identify thresholds which are both measurable and biologically meaningful. From a management perspective, a threshold provides a defined boundary beyond which impacts are acted upon: crossing these thresholds will trigger management actions to address the problem.

To give an example, the ESIA process for a marine oil and gas project has identified a species of high biodiversity value – leatherback turtles - within the project area and determines there is a high probability of impact from port activities such as the construction of a loading jetty and/or transmission lines. This species is therefore monitored frequently over multiple nesting seasons, using nesting beach counts as an indicator. A suitable threshold of X% reduction in nesting females is identified in conjunction with BES specialists. If the number of nesting leatherback females falls more than this threshold within a defined period, then more intensive monitoring and investigation must be undertaken to identify the cause of the decline. If further declines are observed, then management will review and adjust activities to fully address the cause of the decline. It should be noted that leatherback turtles are considered indicators of ecosystem health through their role as predators of jellyfish - when turtles decline, jellyfish increase and this in turn impacts fish recruitment, which has a knock-on effect on the food web, and ultimately can negatively impact fisheries. Thus, carefully selected indicators can provide feedback on multiple BES values.


Credit: JABRUSON

Thresholds help inform progress against targets in monitoring and evaluation plans. With any change to the environment, through operational activities or minimisation or restoration activities, the ecosystem can suffer impacts where a 'tipping point' may be reached, leading to a change in the ability of the ecosystem to function and produce particular ecosystem service/s. When an ecosystem reaches or passes such a tipping point, recovery can be difficult, expensive and lengthy. Degradation and loss to ecosystems can be irreversible (e.g. species extinction and state change of habitat), expensive to rectify (e.g. translocation of species and removing pollution), take significant time to rectify (e.g. restoration of mature primary forest) or require a significant input of energy and resources (e.g. active restoration of habitats and eradication of invasive species). By evaluating and relating changes to ecosystem services against thresholds, negative trends can be determined and prevented by adapting management activities to suit. Of course, there are many impacts to ecosystem components which cannot be predicted and evaluated against thresholds (e.g. natural disaster events). Investing in a structured M&E plan which includes an understanding of tipping points and identifies biologically meaningful thresholds should minimise the risk of complex recovery programmes.

It is important that thresholds are defined in close consultation with marine BES specialists. It should be noted that thresholds can vary considerably and may, for some biodiversity and ecosystem services values, need to be set very low, especially where the value is highly irreplaceable and where potential losses may be irreversible. Further, thresholds may not be appropriate for all BES values, including some cultural ecosystem services.

7.4. M&E planning

An M&E plan is a detailed program of work which sets out what monitoring activities will take place, when and by whom, and how that information will feed back into management decisions. This ensures management understands resource commitments from the outset. A defined plan is necessary to ensure adherence to a standard approach and comparability between survey events. M&E plans should contain the following components[303]:

- clearly stated BES target and objectives borne from legal, lender and/or good practice requirements;
- clearly defined indicators for performance and impact;
- identification of thresholds at which action must be taken to address negative trends, accounting for the health and function of the ecosystem
- definition of study area, survey design and sampling strategy;
- details of how often monitoring and evaluation will be done, when, and by whom;

- details of resources required, including budget and summary of necessary training and capacity building;
- summary of intended audience for the M&E and how information will feed back into management decisions through adaptive management;
- quality assurance and quality control to ensure sampling meets required standards and remains comparable between sessions; and,
- Periodic review to cross-check M&E outputs against targets and objectives.

Consultation

To be successful, an M&E plan must be developed in consultation with key stakeholders, including those stakeholders dependent upon potentially affected ecosystem services. This requires meaningful engagement with a range of groups, including communities local to the operation, ecosystem services user groups, marine BES experts and regulators. FPIC principles should always be applied. Consultation should be a continuous process which engages key stakeholders in the purpose, planning, implementation and review of M&E activities.

Resources

It is important to acknowledge that M&E activities can incur significant costs which must be factored into financial planning as early as possible in the project cycle. These costs must be judged against the business case for M&E, with the predominant benefit being that M&E enables an operation to track its environmental performance towards compliance with legal, lender and good practice targets.

Independence

An operation's M&E activities should provide objective and impartial information in order to track progress towards agreed targets. Therefore, consideration should be given to the independence of any persons or organisations collecting such information. Independence may be viewed differently for each of monitoring and evaluation: monitoring is an integrated part of management and therefore is commonly undertaken by internal teams, whereas evaluation is periodic and 'big picture' and may be best undertaken by an external party[299].

7.5. Monitoring BES

The process of M&E for BES is not as straightforward as for other environmental aspects, such as air or water quality for which there are well established global standards and benchmarks[iv]. As stated previously, marine ecosystems are dynamic, interconnected and highly complex. The diversity of life is not evenly spread through the marine system, with some areas e.g. coral reefs, harbouring a concentrated diversity of life, and others, such as the mid-ocean ridge, containing a relatively low diversity of rare and highly specialised species.

Credit: Sue Murray-Jones/FFI

Furthermore, the BES values of an area may undergo considerable fluctuations as a result of natural processes. For example, information on the species that are known or likely to occur within the project development and offset areas needs to take into account seasonality and annual variation: some species are only evident during a particular time of year and, in some ecosystems, certain species are only evident for short time periods over multiple years.

Such natural variations need to be identified and monitored so that they can be taken into account in evaluating the results of project interventions[303]. However, determining changes in natural systems can be a lengthy process, particularly if the relative importance of natural cycles and anthropogenic changes is to be properly understood[301]. This requires an informed sampling strategy and regular monitoring over longer time frames, especially where pronounced seasonal variations occur.

iv See OGP (2012) for examples of legislative and good practice standards used in marine environmental monitoring.

Integrated monitoring

An ecosystem approach should be applied to M&E, as for all aspects of BES management. This demands an integrated approach to the assessment of biodiversity and ecosystem services.

An ecosystem approach should take into account the patterns and processes of the ecosystem, such as species abundance and richness, habitat heterogeneity and dispersal. These patterns are often underpinned by processes or functions, including genetic flow, biomass production, carbon sequestration and nutrient cycles. Ecological patterns and processes are dynamic in their variability and responses to change, often influenced by human-induced activities or abiotic and climatic changes. Such patterns and processes may not be easy to monitor, but their inclusion will enable a deeper understanding of the presence and persistence of the BES being monitored, and likely influencers of change within the environment.

From a practical standpoint, it is important to integrate field work relating to BES wherever possible. This should not only reduce costs but should also maximise benefit from the outcomes. To give an example, mangroves are considered to be a high value habitat by a number of IFIs, so operations in close proximity to mangroves would be likely to need to monitor them. An integrated approach to monitoring mangroves would combine in a single study not only the biodiversity value of the habitat, e.g. area and quality, but also the provision of ecosystem services, e.g. production of crabs and the use of the habitat as a nursery area for a wide range of fish species. The role of the habitat as storm protection and for cultural values could also be explored. Thus, an integrated approach should avoid duplication of effort and increase the efficiency of monitoring.

Further, BES monitoring should be integrated with wider environmental monitoring. Operations will typically undertake some form of regular environmental monitoring, be this of operational discharges, physical properties of the water column, or the benthic substrate. Such monitoring is well described elsewhere, e.g. the OGP (2012) document[300]. Combining environmental monitoring with that for BES will provide a deeper understanding of the impacts of human activities upon ecosystems, and specifically those high value elements of BES being monitored.

7.6. Methods of assessment

The practicalities of collecting information on BES means different approaches may be required for each BES component. Biodiversity is usually monitored through quantification of species (e.g. population size, threat status), habitats (e.g. area, quality) or processes (e.g. decomposition) based upon information from direct field surveys, remote sensing, or in some cases, proxies.

By contrast, ecosystem services reflect the human value and use of resources and so often require a sociological approach to their assessment. This means talking to people about their ecosystem services use, asking them to identify priorities and trends in stocks and flows of ecosystem services over time, which is normally the case for provisioning and cultural ecosystem services. In some cases a quantified biological approach may also be appropriate for ecosystem services, for example habitat area x quality metrics may be applied to collection fisheries. For many ecosystem services, a blend of sociological and quantified biological approaches may be used. See Table 10 and Appendix 4 for further information on considerations for measuring and monitoring ecosystem services.

Though approaches to BES are considered individually below, the design and assessment of surveys and interpretation of results must be integrated. This will enable a greater understanding of the relationship between biodiversity and ecosystem services, the underlying ecosystem processes that support both, and should promote understanding of human influences upon BES within the area of study

Monitoring Biodiversity

The process of establishing biodiversity monitoring for oil and gas operations is well covered by the Energy and Biodiversity Initiative document 'Biodiversity Indicators for Monitoring Impacts and Conservation Actions'[301], which, though more than 10 years old, remains relevant. This document explains among other things the process of selecting indicators for impacts, the need to tailor indicators for each stage of the project cycle, the importance of effective stakeholder engagement and some of the pitfalls of monitoring biodiversity.

Monitoring biodiversity in relation to marine oil and gas operations encompasses a wide range of activities, from monitoring the water column and benthic habitats (i.e., sediments and soft and hard-bottom fauna), to assessing the effects on migrating birds of flaring and light from offshore installations, undertaking studies on the effects of seismic activity on fish and marine mammals, or determining changes to marine community structure in relation to operational activities. Below is a selection of indicators for species, habitats and ecosystem processes. Note that this is not intended to be a comprehensive listing, but rather an illustration of the range of indicators that could be employed.

Table 9: A selection of potential indicators and thresholds suitable for monitoring biodiversity (adapted from EBI[301])

Type	Class	Indicator	Threshold	Rationale	Limitations and suitability
Species	Globally threatened / data deficient species	Population studies (e.g. direct observation, photo surveys, tagging)	% change in abundance % reduction in habitat area	By comparing changes in population status over the years, this indicator tracks changes to key species within the study area	Target species may act as surrogates for health of the entire system. The indicator may not reveal short-term changes. Not all taxa have been comprehensively assessed
	Restricted range species	Population studies	% reduction in range % reduction in abundance	Restricted range species are especially important because they are found only in certain ecosystems or areas and are thus vulnerable to change	As above
	Alien invasive species (AIS)	Identify and conduct population / abundance studies for all priority AIS	% increase in cover	A company's activities may promote AIS in certain circumstances, e.g. by improving access to an area	Can be difficult to judge whether a particular AIS results from project or external activity. Monitoring population / abundance trends will provide an early warning system.
	Species used by local communities	Identification of species used; monitoring of population trends or abundance	% reduction in abundance	Project activities may lead to an increase in the use of certain species, e.g. by improving access to a new area.	If species use by local communities can be attributed to the project then the impacts of this use upon biodiversity should be monitored
Habitat	Project area overlap with / proximity to areas of conservation priority (PAs, KBAs, MPAs, World Heritage Sites, etc)	Area of overlap; proximity to identified conservation areas	% overlap with boundary or buffer zone	Areas identified to be a conservation priority indicate potential high risk of adverse impacts for BES and should be carefully assessed	Accurate demarcation of boundaries may be an issue for some concessions and protected areas; impacts need to be considered independently of boundary overlap.
	Area of land / sea within project area with specific biodiversity management objectives	Area under biodiversity management; quality of habitat	% reduction in area / quality of habitat	Established biodiversity management programmes should be respected	Land may be set aside for biodiversity management within a project's area of operation
	Globally threatened habitats	Area, quality of habitat type	% reduction in area / quality of habitat	Global threat is increasingly being assessed at the habitat level	Only a limited number of habitat types have thus far been assessed for threat
Process / relationship	Primary production	Photosynthetic activity (derived from remote sensing)	% change in primary production	Will help to determine primary energy input into the marine system	Primary production shows marked seasonality in temperate and polar oceans
	Food webs	Key species and roles within each trophic level	% change of key species within a given trophic level	Will help determine community structure and energy flow	It takes considerable time and resources to develop an accurate picture of a food web
	Decomposition	Presence / abundance of decomposers	% reduction in abundance /species richness of decomposers	Decomposers are essential to nutrient cycling	It may be difficult / expensive to sample benthic decomposers in deep water
	Migration	Track migration patterns of highly mobile species through tagging / counting	% reduction in abundance	Highly mobile species are vulnerable to threats due to reliance on a wide range of habitats at different stages of the life cycle	Tagging is expensive, only a small number of individuals are possible to tag

Monitoring ecosystem services

Several documents provide guidance on the development of ecosystem service indicators, including UNEP-WCMC guidance, Joint Research Centre review of ecosystem services indicators[304], Biodiversity Information Systems for Europe indicators for marine ecosystems[305] and World Resources Institute guidance[306].

Ecosystem services assessments are typically focused on investigating, within a particular location, what ecosystem services are provided, who benefits from these services, and how change – man-made or natural – might affect the delivery of these services (see also Appendix 4). However, the cultural services provided by ecosystems continue to be underemphasised in many ecosystem services assessments and decisions as they are often considered complex and difficult to measure (see Box 31).

Box 31: Assessing Cultural Ecosystem Services

Cultural ecosystem services (CES) are the benefits people obtain from **ecosystems** through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. CES provide a fundamental contribution to human wellbeing. While they are complex and can be difficult to describe and to measure, it is widely acknowledged that CES are as important as other types of ecosystem services, and need to be better incorporated in decision making.

Why is it so important to assess CES?

- **CES are integral to human wellbeing** through spiritual, aesthetic, religious or other values;
- **CES are often unique and irreplaceable** due to their context-specific nature;
- **CES benefits can be extremely significant** in financial terms[i];
- **Ignoring CES can have costly repercussions** both financially and in terms of public outcry[ii]; and
- **Incorporating CES into decisions can strengthen community support** for a project.

There are many different approaches to the assessment of CES[iii] and it is an area subject to a growing body of research and application. FFI's Guidance for the Rapid Assessment of Cultural Ecosystem Services (GRACE) provides useful introduction to CES and guidance relating to their assessment. It is a guide for those needing to assess which CES people value, how these contribute to their wellbeing, and how changes to ecosystems might affect the delivery of these services and wellbeing derived from them.

GRACE is designed to:

- Be **practical, flexible and participatory,** being more of a guide than a tool kit**;**
- Provide **non-monetary assessments** of CES; and
- Be **complementary** with other methods of ecosystem service assessment

Assessment of CES must always be undertaken in a culturally sensitive manner and using **FPIC** principles. Local language should be used in interviews and group discussions. It can be difficult for people to describe feelings about the seascape or nature, so time, patience and multiple approaches to the same topic may be required.

i For example, the spiritual values of sites in northern Australia were considered so important by local people that they decided to protect the land, giving up earnings of AUD$750 million, rather than allowing it to be mined.

ii The UK Government's decision in 2011 to sell 258,000 ha of state-owned woodland was motivated by economic arguments, but they failed to consider the benefits these woodlands provided to the public. Following protests by over half a million people, the Government was forced to abandon plans to sell them, which could have been avoided with more careful assessment of the benefits provided by the woodlands.

iii See, for example: UNEP-WCMC Cultural Services

A wide range of indicators will typically be required to monitor ecosystem services. Indicators for provisioning ecosystem services may take the form of quantitative measures or numbers linked to yield, production, areas or financial figures, yet this may not account for the full benefit a stakeholder receives from an ecosystem service, such as accessibility and value to livelihood. Therefore, it is usual for a suite of qualitative indicators to be applied to represent the relative importance of the ecosystem service to the user, its accessibility, trends in availability and condition and its replaceability. In combination, such quantitative and qualitative indicators provide a more complete representation of ecosystem services value and of ecosystem function.

M&E for ecosystem services should be developed in consultation with a range of stakeholders and must be relevant for company management objectives and systems.

A summary of marine ecosystem services indicators are included in Table 10 below. Note that this is not a comprehensive listing but rather illustrative of the wide range of indicators to be considered.

Table 10: A selection of potential indicators and thresholds for representing and measuring marine ecosystem services (from Common International Classification of Ecosystem Services (CICES) v4.3)

Type		Class	Indicator	Threshold
Provisioning	Nutrition	Wild animals	• Yield of catch: volume, species caught, richness/proportion of species • Presence of habitats of fish assemblage/ nurseries • Fishing method, effort, cost • Market cost of fish • Food/prey availability • Trends in yield, fishing effort, fishing method, consumption patterns • Importance to livelihood	• % reduction in catch • % reduction in abundance of nurseries / area of habitat • % increase in catch per unit effort • % increase in market cost • Relative change in importance to livelihood
		Animals from in-situ aquaculture	• Yield of product: volume, species farmed • Aquaculture method, effort, cost • Market cost • Trends in yield, industry effort and methods, consumption patterns • Importance to livelihood	• % reduction in yield • % increase in market cost • Relative change in importance to livelihood
		Plants and algae from in-situ aquaculture	• Yield of product: volume, species farmed • Aquaculture method, effort, cost • Market cost • Trends in yield, industry effort and methods, consumption patterns • Importance to livelihood	• % reduction in yield • % increase in market cost • % change in consumption patterns
	Water	Surface water for drinking	• Water quality • Effort, cost of water collection • Volume over time	• Reduction in water quality (refer to international standards) • Increase in effort or cost per unit of water
		Surface water for non-drinking use	• Water quality • Effort, cost of water collection • Volume over time	• Reduction in water quality (refer to international standards) • Increase in effort or cost per unit of water
	Materials	Materials from plants and algae for processing	• Yield of collection: volume, species richness • Presence of habitats or species assemblages • Collection method, effort, cost • Market cost of product • Trends in yield, collection method, effort	• % reduction in yield • % change in species assemblages • Increase in effort or cost per unit

Type		Class	Indicator	Threshold
Regulation and maintenance	Waste mediation	Bio-remediation, filtration and sequestration by microorganisms, algae, plants and animals	• Water quality, chemical composition, turbidity • Species assemblages and richness • Presence of habitat harbouring species	• Reduction in water quality (refer to international standards) • % change to species richness • % reduction in habitat
		Filtration, accumulation and sequestration by ecosystems	• Water quality, chemical composition, turbidity • Species assemblages and richness • Presence of habitat harbouring species	• Reduction in water quality (refer to international standards) • % change in key chemical concentration • % change to species richness • % reduction in habitat • Increasing concern / priority given to water-related diseases
		Dilution by atmosphere and marine systems	• Water quality, chemical composition, turbidity • Atmospheric conditions	• Reduction in water quality (refer to international standards) • % change in key chemical concentration • % change to species richness • % reduction in habitat
	Flow mediation	Stabilisation and control of erosion rates	• Presence of species or habitats • Habitat and sediment quality • Slope	• % change to key species • % reduction in habitat • Perceived change to sediment volume
	Buffering of flows	Transport and storage of sediment	• Presence of species or habitats • Habitat and sediment quality • Slope • Sediment loads	• % change to key species • % reduction in habitat • Perceived change to sediment volume
		Flood protection	• Presence of species or habitats • Habitat quality • Slope • Climatic variables, rainfall • Perceptions of flood protection trends	• % change to key species • % reduction in habitat area / quality • Change in perception
		Storm protection	• Presence of species or habitats • Habitat quality • Climatic variables, rainfall • Perceptions of storm protection trends	• % change to key species • % reduction in habitat area / quality • Perceived reduction in storm protection
Regulation and support	Physical, chemical and biological conditions	Pollination	• Presence of invertebrate pollinators • Recruitment of flora	• % reduction in abundance / species richness of pollinators • % reduction in recruitment of flora (e.g. seagrass)
		Maintaining nursery populations and habitats	• Presence of habitats of fish assemblage/ nurseries • Food/prey availability • Yield of catch: volume, species caught, richness/proportion of species • Trends in yield, fishing effort, fishing method, consumption patterns	• % change to key species • % reduction in habitat • % reduction in yield • % change in catch per unit effort • Perceived reduction in fish recruitment
		Pest control	• Presence of pest species, blooms • Habitat quality • Natural species assemblages and richness • Water, air, sediment quality and composition	• % increase in pest species • % change in species richness • % reduction in habitat area / quality • % change to species assemblage / key species
		Decomposition and fixing processes	• Habitat quality • Natural species assemblages and richness • Water, air, sediment quality and composition	• % increase in pest species • % change in species richness • % reduction in habitat area / quality • % change to species assemblage / key species
		Water chemical conditions	• Water chemical composition • Nutrient retention • Species assemblages • Presence of pest species, blooms	• % change in key chemical concentration • % change to species assemblage / key species • % increase in pest species • % change in species richness • % reduction in habitat area / quality • Increasing priority / concern given to water quality

Type		Class	Indicator	Threshold
		Atmospheric conditions	• Volume greenhouse gas emissions over time • Net primary productivity • Trends in climatic changes	• Reduction in primary productivity • % change in atmospheric composition
Cultural	Physical interaction	Leisure activities	• Tourist numbers, tourism industry financial figures • Social wellbeing surveys • Presence of important species and habitats, quality	• % change in tourism numbers • Change in perception of wellbeing • Reduction in key species, habitats
		Heritage and cultural activities and interactions	• Tourist numbers, tourism industry financial figures • Social wellbeing surveys • Local value of cultural activities • Presence of species and habitats, quality • Access to important species, habitats	• % change in tourism numbers • Change in perception of wellbeing • Reduction in key species, habitats
		Aesthetic and visual presence	• Landcover • Change in landcover types, urbanisation trends • Local value of aesthetics, e.g. viewshed • Social wellbeing surveys	• % change in land cover • % increase in urban development • Change in perception of wellbeing
	Spiritual interaction	Sacred and religious sites of importance	• Landcover • Change in landcover types, urbanisation trends • Local value of aesthetics, e.g. viewshed • Social wellbeing surveys • Access to important species, habitats, areas	• % change in land cover • % increase in urban development • Change in perception of wellbeing • Reduction in key species, habitats
	Other cultural outputs	Existence	• Tourist numbers, tourism industry financial figures • Social wellbeing surveys • Presence of species and habitats, quality	• Change in tourism numbers • Change in perception of wellbeing • Reduction in key species, habitats

7.7. Review and revise

Any M&E programme should be reviewed on a regular basis. First, there should be ongoing quality assurance and quality control to ensure the required standards are being met and to provide assurance of quality and consistency of results. Second, M&E activities should be regularly reviewed against BES targets and objectives to ensure they continue to deliver the desired outputs. Targets and objectives may change through the life of an operation in response to new legislative or lender requirements, or emerging good practice. M&E methodology should also be reviewed as advances in technology may offer efficiencies in data collection. Finally, as our understanding of the relationship between people, biodiversity and ecosystem services improves, there may be the opportunity to adopt more integrated and efficient approaches to M&E.

8 Glossary of key terms

Rather than having a lengthy glossary as an appendix to this GPG readers are referred to the following resources for definitions of technical terms:

- UNEP-WCMC's Biodiversity A to Z website for technical terms relating to biodiversity and ecosystem services.
- SBM Offshore Glossary of Terms for terms relating to the oil and gas industry.
- Business and Biodiversity Offsets Programme (BBOP) Glossary (2012) for technical terms relating to biodiversity offsets.

Here we provide a limited glossary that defines key terms central to this GPG.

Adaptive management: A continuous process of revising management plans to take results to date into consideration. Objectives are set, actions to manage natural resources are taken, monitoring and evaluation of the affected ecosystem and human responses are assessed, results are compared against expectations, and future actions are adjusted, with each iteration of activity based on past experience. Such management is adaptive, because lessons learned are put in practice in the next cycle[6].

Biodiversity: Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. Biodiversity is a compound word derived from 'biological diversity' and therefore is considered to have the same meaning[1].

Biodiversity value: Biodiversity value refers to the importance or sensitivity of biodiversity and may relate to its contribution towards the function and integrity of affected ecosystem/s, persistence of biological diversity, maintenance of ecosystem service provision, and/or importance to society (e.g. intrinsic values, cultural significance).

Compensation: Generally, compensation is a recompense for some loss or service, and is something which constitutes an equivalent to make good the lack or variation of something else. It can involve something (such as money) given or received as payment or reparation (as for a service or loss or injury). Specifically, in terms of biodiversity, compensation involves measures to recompense, make good or pay damages for loss of biodiversity caused by a project[6].

Ecology: A branch within biology which addresses the relationships between living organisms and their environment. Ecology can be addressed at a number of scales; it also includes the relationships of a particular organism with its environment[1].

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit[1].

The **ecosystem approach**, defined by the Convention on Biological Diversity, is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way[1].

Ecosystem engineer: An organism that directly or indirectly modulates the availability of resources to other species, by causing physical state changes in biotic or abiotic materials. In so doing, they modify, maintain and create habitats[1].

Ecological patterns represent the composition and spatial attributes of biodiversity, such as species abundance and richness, habitat heterogeneity and distribution. Patterns are often underpinned by ecological processes (see below).

Ecological processes structure ecosystems and contribute to ecosystem function. Ecological processes may include, for example, predator-prey trophic interactions in a food web, inter- or intraspecific competition, connectivity and dispersal, etc. Ecological patterns (see above) and processes are dynamic in their variability and responses to change, often driven by human-induced activities or abiotic and climatic changes.

Ecosystem function: An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy. Ecosystem function is equivalent to ecosystem process[1].

Ecosystem structure: The biophysical architecture of an ecosystem[1]. This refers to the physical organisation of the living and non-living components of an ecosystem, including the species present and where they are found; physical structures e.g. reefs, rocky substrate or canyons, the amount and distribution of sediment, nutrients, water and other materials; and climatic conditions such as temperature, rainfall and light[2].

Ecosystem services: Benefits people obtain from ecosystems[1], including:

- Provisioning services - goods or products obtained from ecosystems such as biological raw materials (e.g. limestone) and food (fish, octopus, seaweed etc.)
- Regulating services - benefits obtained from the regulation of ecosystem processes such as the regulation of floods and climate, and waste attenuation.
- Cultural services - benefits people obtain from ecosystems such as recreation, spiritual enrichment, cognitive development, reflection sense of place[3].
- Supporting services - natural processes that maintain the other services such as primary production and nutrient cycling.

Food web: A graphical model depicting the many food chains linked together to show the feeding relationships of organisms in an ecosystem. It differs from a food chain in a way that the latter is a linear system showing a succession of organisms whereby each species is eaten in turn by another species. Food web is a more complex network of ***what eats what*** in a particular ecosystem. The position that an organism occupies in a food chain or food web is called the trophic level[4].

Habitat means the place or type of site where an organism or population naturally occurs[1]. The presence, survival and reproduction of a population will depend on the suite of resources (food, shelter) and environmental conditions (abiotic and biotic) provided by the habitat[5].

Irreplaceability: The number of additional spatial options available for conservation if the biodiversity affected by a project were lost. Where biodiversity occurs at many sites (low irreplaceability) then many options exist for conservation, whereas where biodiversity is restricted to one or a few alternative sites (highly irreplaceable) then few options exist for conservation[6].

Keystone species: Species whose influence on ecosystem function and diversity are disproportionate to their numerical abundance. Although all species interact, the interactions of some species are more profound and far-reaching than others, such that their elimination from an ecosystem often triggers cascades of direct and indirect changes on more than a single trophic level, leading eventually to losses of habitats and extirpation of other species in the food web[1].

Multiplier: In offsetting, use of a 'multiplier' represents a decision made by an offset planner to increase the area of an offset by a certain factor, with the aim of improving the chances of achieving no net loss[6], and addressing perceived uncertainty or risk.

No net loss & Net Gain: 'No net loss' aims to counterbalance adverse impacts of a development project or programme by positive actions that restore and conserve biodiversity such that there is no overall reduction in the type, amount or condition of biodiversity. It implies a legacy of no overall harm compared to what would have occurred in the project's absence. Net gain is achieved when there is a positive impact on biodiversity that not only balances but exceeds losses caused by development impacts.

No net loss and net gain targets should take account of species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity. No net loss and net gain targets typically focus on biodiversity. However, gains may be realised for ecosystem services, particularly where biodiversity and ecosystem services are considered in an integrated way throughout planning and implementation and where actions to remedy adverse impacts result in benefits accruing within the project affected landscape or seascape (i.e. where the people affected by development project impacts on particular ecosystem services are also the beneficiaries of mitigation actions).

It is important to recognise that no net loss and net gain can be understood at different scales, from a specific single development project, to developments across a seascape or the entire marine environment of a nation. It is important to be explicit about scale when referring to such targets.

No net loss or net gain must be demonstrated and supported by evidence. A variety of methods exist to quantify residual losses of biodiversity and to determine whether these are fully compensated for by gains made through the application of the mitigation hierarchy. Appropriate methods and metrics will vary from site to site, and specialists are usually required to undertake the quantification that is necessary to demonstrate that a target of NNL or net gain has been achieved.

Precautionary approach: For the purposes of this document, precautionary principle and precautionary approach are considered synonymous. As phrased in the Rio Declaration, the precautionary principle states that: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation"[7].

Protected area: A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of biodiversity with associated ecosystem services and cultural values[8].

Resilience: The ability of an ecosystem to recover and maintain diversity, integrity and ecological processes following disturbance

Seascape: A spatially heterogenous area of coastal or underwater landscape composed of interacting ecosystems; an area of large extent composed of an interacting mosaic of ecosystems and shaped by the action and interactions of nature and/or people.

Stakeholder consultation: The undertaking of discussions with stakeholders (i.e. those people or groups of people who can affect or are affected by an organisation, strategy or project), whereby a number of options for project development are offered, and the feedback of stakeholders is listened to. Stakeholder consultation is most commonly carried out through focus groups or interviews.

Stakeholder engagement: A process that includes the fair and active involvement of all stakeholders in identifying problems, formulating plans and making and implementing decisions. Stakeholders should be encouraged to provide their own ideas, and participatory activities should be carried out to encourage joint analysis, planning and decision-making.

Tenure: The term tenure is used to describe the 'bundle of rights' that determine the conditions for access, use, management, exclusion of other users, and 'alienation' of land and other resources. These rights usually come with associated responsibilities and constraints on how resources are managed. In simple terms, **tenure systems** define who can use what resources for how long, and under what conditions. Tenure is most commonly used in relation to land but the same bundle of rights applies to other natural resources, including freshwater, coastal and marine resources[9].

Threatened species - Species classified as critically endangered, endangered, vulnerable or near threatened according to global, regional or national Red Lists and other relevant regional or national legislation.

Top (apex) predator – A predator residing at the top of a food chain that has no natural predator within its ecosystem

Vulnerability: Vulnerability indicates risk of imminent loss and so reflects irreplaceability over time. Measures of vulnerability are based on features that indicate risk of impending loss. As a general rule, components which are isolated and rare and have long generation times and low mobility are more vulnerable[6].

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Credit: Michangelo Pignani/FFI

10 Appendices

Appendix 1: Marine policy and the oil and gas industry

Appendix 1 provides a concise introduction to national and regional policy for the oil and gas industry in marine environments, commencing with examples of good policy and concluding with UN conventions relating to the oceans.

What constitutes good marine policy?

Policy consists of high level statements explaining the position of government/s on a particular issue of importance. Policy should clearly outline roles and responsibilities, define the scope of activities, and provide a high-level description of the controls that must be in place. It should also refer to the standards and guidelines that support it. Policy is then mandated through legislation and regulation.

Good practice marine policy for the oil and gas industry should include many of the following characteristics[1]:

- Clearly established (and ideally quantitative) targets and thresholds for operations;
- A comprehensive list of permitting requirements and respective statutory authorities for marine operations;
- Reference to existing regulations for permitting, including undertaking an ESIA;
- Explicit monitoring, reporting and compliance requirements;
- Clearly identified regulatory and enforcement bodies;
- Defined penalties and remedial actions in the event of non-compliance;
- A framework for the acquisition, management and relinquishment of concessions;
- Free access to detailed policy guidance information, ideally online;
- Referral of proposals identified as likely to have significant BES impacts to the relevant government authorities for assessment;
- Linkages to national biodiversity and sustainable development strategy and priorities; and
- Emphasis on avoidance of environmental impacts over mitigation.

Policy can be set at the international, national, or sub-national level. For example, in Europe, the European Union has set Europe-wide marine policy through its Marine Directive[2], which is then transposed into national legislation in individual countries. Many countries have national-level policies pertaining to development in the marine environment, and in some cases, national-level policy is devolved to the sub-national level, e.g. in Western Australia, where State-level policy and regulations govern oil and gas operations.

The level and complexity of marine policy varies greatly from country to country. In the most advanced cases multi-layered policy covers a wide range of marine activities – including oil and gas – and provides clear guidance for compliance. At the other end of the scale, policy may be fragmented or contradictory, or may not exist at all.

Variation in the quality and coverage of policy creates challenges for the oil and gas industry with companies having to navigate many different policy contexts when operating in multiple countries. Sometimes, the regulatory system within a country may be contradictory – in Australia for example, the oil and gas industry claims it faces overlapping state and federal laws with duplicative and inconsistent requirements[3]. A comprehensive legal review of existing policy in any new country of operation will be necessary as well as a comparative assessment with internal corporate policy and standards, and the safeguards and standards of any financial institution from which finance may be sought. Companies in pursuit of good practice may wish to go beyond compliance particularly in situations where company policy and/or international best practice exceed regulatory requirements.

UN Regional Seas

The Regional Seas Conventions and Action Plans[4] is the world's only legal framework for protecting the oceans and seas at the regional level and was launched in 1974 in the wake of the 1972 United Nations Conference on the Human Environment. The Regional Seas Programme aims to address the accelerating degradation of the world's oceans and coastal areas through the sustainable management and use of the marine and coastal environment. Today, more than 143 countries participate in 13 Regional Seas programmes established under the auspices of UNEP: Black Sea, Wider Caribbean, East Asian Seas, Eastern Africa, South Asian Seas, ROPME Sea Area, Mediterranean, North-East Pacific, Northwest Pacific, Red Sea and Gulf of Aden, South-East Pacific, Pacific, and Western Africa.

The United Nations Convention on the Law of the Sea (UNCLOS)[5], also called the Law of the Sea Convention or the Law of the Sea Treaty, is the international agreement that defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. As of

June 2016, 167 countries and the European Union have joined in the Convention. The Convention has introduced a number of provisions, including the setting of sovereign limits, navigation rights and rules, archipelagic status and transit regimes, exclusive economic zones, continental shelf jurisdiction, deep seabed mining, the exploitation regime, protection of the marine environment, scientific research, and settlement of disputes.

The Convention sets the limit of various areas, measured from a carefully defined baseline, including definitions of internal waters, territorial waters, archipelagic waters, contiguous zones, exclusive economic zones and continental shelf, each with defined physical boundaries and specific rights and regulations. The Convention further establishes general obligations for safeguarding the marine environment and protecting freedom of scientific research on the high seas, and also creates an innovative legal regime for controlling mineral resource exploitation in deep seabed areas beyond national jurisdiction, through an International Seabed Authority and the Common heritage of mankind principle.

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Appendix 2: Lender safeguards and standards

Appendix 2 provides a concise introduction to the environmental and social safeguards and standards of International Finance Institutions (IFIs), focusing specifically on safeguards for biodiversity.

Environmental and Social Safeguards

International Finance Institutions (IFIs) including the International Finance Corporation (IFC), European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD), African Development Bank (AfDB) and Asian Development Bank (ADB) among others, play an important role in the financing of offshore oil and gas developments around the world and in driving improvements in environmental and social performance within the oil and gas industry.

To improve sustainability outcomes of their investments and manage environmental and social risk, IFIs have developed Environmental and Social Safeguards (ESS). These ESS set out the IFI's standards and procedures for screening the environmental and social risk of the interventions the IFI supports and the level of assessment and mitigation or management that they and their clients should apply. They provide a framework for good practice for public and private sector proponents developing projects across a range of sectors, including oil and gas.

A key element of most safeguard systems is the use of a categorisation system for identifying environmental and social risk. Such systems are applied at an early stage in the project cycle and take account of the type, scale and location of the programme or project and any environmentally or socially sensitive and/or high value receptors in the project's area of influence, as well as the likelihood that specific safeguards (e.g. for involuntary resettlement, biodiversity conservation, cultural heritage) would be triggered. The ESS systems of different IFIs are harmonised to a high degree – having a similar structure, requiring systematic screening of environmental and social risks and covering a common set of environmental and social issues.

Safeguards for biodiversity

Most IFIs have a biodiversity-focussed safeguard including, for example:

- The IFC's Performance Standard (PS) 6 on '***Biodiversity Conservation and the Sustainable Management of Living Natural Resources'*** (2012)[i] [1].
- The EBRD's Performance Requirement (PR) 6 on '***Biodiversity Conservation and Sustainable Management of Living Natural Resources***' (2014)[2].
- The EIB Environmental and Social Standard 3: '***EIB Standards on Biodiversity and Ecosystems'*** (2013)[3].
- The AfDB's Operational Safeguard 3 '***Biodiversity, renewable resources and ecosystem services***' (2013)[4].
- The ADB's Environmental Safeguard on '***Biodiversity conservation and sustainable natural resource management***' (2012)[5].
- The Inter-American Development Bank's Environmental Safeguard 9: '***Natural Habitats and Cultural Sites'*** (2009)[6].

These safeguards outline the standards and steps required by each respective IFI in regards to biodiversity management, and typically include the characterisation and assessment of biodiversity associated with the project land or seascape. This involves determining the presence and location of any protected or internationally recognised areas and characterising habitat along a natural to modified gradient. The critical nature of habitat (i.e. its biodiversity value or sensitivity) is determined according to attributes outlined in the ESS (e.g. habitats important for critically endangered or endangered species and unique or threatened ecosystems), with the most sensitive biodiversity features defined as critical habitat (CH). For some IFIs (e.g. EIB) there is a presumption of criticality, given the intrinsic value of biodiversity, and the burden of proof is on the client to demonstrate the absence of critical habitat on the project site.

The process of determining CH helps to identify where mitigation measures, particularly impact avoidance, should be prioritised in line with the application of the mitigation hierarchy. This is normally undertaken as part of the initial (pre-development) Environmental and Social Impact Assessment process and retrospective application to operational sites can be considerably more difficult.

Areas identified as CH are considered highest priority and demand the most stringent avoidance and/or mitigation measures. Many IFIs will not finance projects that are anticipated to result in significant adverse impacts to CH. Where no viable alternatives exist, IFIs will demand that certain biodiversity outcomes be demonstrated for the project to be considered for investment.

i The 2012 version of the IFC's PS have been adopted by 81 Equator Principle Financial Institutions in 36 countries and uptake has been encouraged by some national governments through endorsement, policy and/or regulation.

Requirements vary across the IFIs. Examples include: no measurable adverse effects on the criteria for which the CH was designated; 'no negative effects on' or 'no net reduction of' critically endangered or endangered species; net gains for critical habitat and the biodiversity values for which the critical habitat was designated; positive conservation outcomes. Achieving these targets demands the comprehensive assessment of direct, indirect and cumulative impacts and rigorous application of the mitigation hierarchy. A robust and appropriately designed, long-term biodiversity monitoring and evaluation programme aimed at assessing the status of critical habitat is required.

For most IFIs, CH would include:

- the presence of, or habitat important for, critically endangered and endangered species
- habitat important for endemic or geographically restricted species
- habitat important for globally significant migratory or congregatory species
- threatened or unique ecosystems
- areas associated with key evolutionary processes
- the ecosystem functions vital to maintaining the viability of critical biodiversity.

Some IFIs also consider a range of other attributes to inform the determination of CH:

- areas crucial for vulnerable, near-threatened or keystone species
- areas highly suitable for biodiversity conservation
- areas that supply ecological networks or provide connectivity
- areas critical for the viability of migratory routes of migratory species
- areas required for the maintenance of biodiversity with significant social, economic or cultural importance to local communities
- areas required for the maintenance of ecosystem functioning and the provision of key ecosystem goods and services
- areas holding key scientific value.

It is important that the process of assessing and characterising the critical nature of the marine environment focuses on promoting a better understanding of the seascape in which the project is to be located. Natural and modified habitat will coexist and range from largely untouched, pristine natural habitats to more intensively utilised and managed modified habitats. Both natural and modified habitats may qualify as CH and areas not considered CH will also hold important biodiversity values and sensitivities that must be sufficiently considered. Projects will typically intersect with a mosaic of habitats with varying levels of disturbance. Moreover, many species will move between habitats over varying temporal and spatial scales thus demanding an ecologically sound and systems level approach. Where projects are likely to have adverse impacts on natural and modified habitats with important biodiversity values it will be critical that these are appropriately addressed through the rigorous application of the mitigation hierarchy.

Approaches adopted to determine the critical nature of habitat vary among the IFIs from systematic criteria-led approaches to those that are more flexible and draw heavily on an understanding of the ecology and conservation priorities of the land or seascape in question when determining CH and the biodiversity values and sensitivities of natural and modified habitat. Some IFIs apply thresholds based on global distribution and representation at a species level and identify CH for the most globally significant sites for a particular species, ecosystem or process. Others evaluate each CH criterion on a case-by-case basis with consideration of national and/or local status and representation, site specificities, and with recognition of genetically distinct subspecies, subpopulations, races and communities.

This is particularly relevant in the marine environment where species distributions are often very widespread but where individuals, communities and subpopulations likely play a very specific or important role in the complex trophic interactions at a very local level, or during a specific period in their life histories. Similarly, migratory species require special consideration as many are now among the most threatened due to the diverse range of pressures they encounter during their extensive movements. Long-term studies also reveal considerable site fidelity and well-defined habitats for many migratory and wide-ranging species[7]. Migratory marine species include many of the world's most charismatic organisms such as marine mammals, sea birds, turtles, sharks, cetaceans and tuna.

Stakeholder engagement and expert advice is emphasised and valued by all IFIs, though the extent to which it is used to guide decision-making varies between IFIs as well as between projects according to the availability of data and the particular sensitivities of the site. For the marine environment, the involvement of marine experts is necessary for determining critical habitat and assessing likely impacts in order to ensure an ecologically sound approach and the robustness and objectivity of results. A precautionary approach to determining the critical nature of habitat is essential, particularly in the marine environment, and is supported or explicitly required by most IFIs.

Integration of ecosystem services within biodiversity safeguards

Ecosystem services are incorporated to varying degrees within the biodiversity safeguards of IFIs. For example, the EIB Standard on biodiversity and ecosystems considers 'areas required for the maintenance of ecosystem functioning and the provision of key ecosystem goods and services' when determining CH, and recommends the assessment of biodiversity dependencies by indigenous groups and local communities and the screening of ecosystem services where these are critical to the support of indigenous communities' livelihoods. EIB goes further, advising, where practical and feasible, that a screening of the dependency of important ecosystem services on biodiversity provided by the site and the larger region in which it is integrated should be undertaken. Baseline and impact assessment requirements for projects likely to affect important ecosystem services are detailed.

The IFC's PS6 also includes specific requirements for the assessment and mitigation of impacts for ecosystem services. The IFC differentiates between ecosystem services over which the client has direct management control or significant influence and where impacts on such services may adversely affect communities (Type I) and/or on which the project directly depends for its operations (Type II). Priority ecosystem services should be identified using a systematic Ecosystem Services Review (ESR) process. The IFC requires that its clients implement the mitigation hierarchy to avoid and minimise impacts on priority Type I ecosystem services and implement mitigation measures to maintain the 'value and functionality of priority services'. Reference to and guidelines for ecosystem services are also included in PS 5, 7 and 8 which relate to the reliance of local communities and Indigenous Peoples on natural resources and the potential for disruption of these resources as a result of project activities.

Supporting the application of ESS

Many of the IFI's have developed detailed guidance to support the interpretation and implementation of their respective ESS. FFI's BES Good Practice Guidance for oil and gas operations in marine environments, alongside other available guidance material produced for the sector (see Appendix 3), can further provide support for the effective application of IFI ESS in the marine environment. However, it is incumbent on the project developer to ensure that projects in receipt of financing from one or more IFIs attend to their specific ESS requirements and the IFI's own guidance on acceptable on procedures and approaches.

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Appendix 3: International industry and sector initiatives

Various international industry and sector initiatives exist to support the oil and gas industry in developing and integrating good practice biodiversity and ecosystem services (BES) management in to their operations. They provide a common space for oil and gas companies to share challenges and experience and to promote continuous improvement in the industry's social and environmental performance. Through these initiatives, practical guidance and tools have also been produced to support good practice BES management. Here we highlight three initiatives - the Energy & Biodiversity Initiative, IPIECA and the Cross-Sector Biodiversity Initiative – as well as a selection of relevant good practice guidance documents available to support good practice BES management.

The Energy & Biodiversity Initiative

As leading energy companies came to recognise the value of integrating biodiversity into upstream oil and gas development, several of them joined with leading conservation organisations to develop and promote biodiversity conservation practices for meeting this goal, forming the Energy and Biodiversity Initiative (EBI). The EBI began in 2001 and produced practical guidelines, tools and models to improve the environmental performance of energy operations, minimise harm to biodiversity, and maximise opportunities for conservation wherever oil and gas resources are developed. The EBI further worked to promote the adoption, dissemination and application of these guidelines across the sector. After more than six years of collaboration, EBI members ceased formal activity as the EBI group. This partnership was instrumental in helping companies understand and address biodiversity conservation and in providing an effective framework for the management of biodiversity across multiple industries.

IPIECA

The global oil and gas industry association for environmental and social issues, IPIECA, was formed in 1974 and has been addressing biodiversity issues since 1992. IPIECA develops tools and guidance whilst also running workshops and developing case-study examples to both communicate and illustrate industry action. In 2002, IPIECA formed a Biodiversity and Ecosystem Services Working Group (BESWG) in partnership with the International Association of Oil and Gas Producers (OGP). The BESWG is an international oil and gas forum working to improve the way the industry recognises and manages impacts to BES, and engages with society on biodiversity conservation issues. Priority areas for the BESWG include:

- integrating BES concepts and management into oil and gas operations by developing science-based good practice tools using the mitigation hierarchy as a reference framework
- engaging with stakeholders within and outside the industry about biodiversity
- understanding regulatory trends and emerging issues
- effectively communicating IPIECA's approach and products, both externally and internally

The Cross-Sector Biodiversity Initiative

The Cross-Sector Biodiversity Initiative (CSBI) is a partnership, formally launched in 2013, between three sectoral associations: IPIECA, the International Council on Mining and Metals (ICMM) and the Equator Principles Association. These associations work together to develop and share good practices relating to BES in extractives industries. CSBI has a strong focus on promoting the transparent application of the mitigation hierarchy in relation to BES and has produced tools and guidance that are becoming increasingly referenced.

Good practice guidance for the oil and gas industry

A range of existing good practice guidance documents are listed below, which are relevant to the management of BES.

The EBI, IPIECA and the Cross Sectoral Biodiversity Initiative have published a range of good practice guidance relating to BES, supported by case studies. These are available from IPIECA's online resource library and CSBI's tools and guidance online.

Good practice guidance on a range of related issues including cumulative impact assessment, strategic environmental assessment and environmental and social impact assessment has also been produced and is available online.

Below we highlight a small selection of good practice guidance relevant to the focus of this GPG. This is not intended to be a comprehensive list and a wide range of other relevant materials are available:

Biodiversity and ecosystem services fundamentals: Guidance document for the oil and gas industry provides guidance for the management of BES impacts, dependencies, risks and opportunities in the oil and gas sector. It sets out a management framework comprised of six interrelated BES management practices along with an overview of tools for application within these practices, examples (case studies) of how these are being applied, and references for more detailed guidance.

The Cross-sector guide for implementing the mitigation hierarchy provides practical guidance, approaches and examples to support operationalising the mitigation hierarchy effectively. It was developed with technical specialists in impact assessment, extractive industry experts and financial institutions, with feedback and input from the non-profit sector. The publication is aimed at environmental professionals working in, or with, extractive industries and financial institutions, who are responsible for overseeing the application of the mitigation hierarchy to biodiversity conservation, while balancing conservation needs with development priorities.

Strengthening implementation of the mitigation hierarchy: managing biodiversity risk for conservation gains was compiled by representatives of the international conservation community (BirdLife International, United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC), the Royal Society for the Protection of Birds (RSPB) and FFI) together with the University of Cambridge. Based on an assessment of case studies and regulatory review from nine regions, the publication considers the drivers for impact avoidance and identifies practical examples of avoidance measures from a range of sectors and geographies. Potential barriers to the widespread adoption of effective impact avoidance are highlighted and recommended actions to strengthen the application of the mitigation hierarchy and maximise impact avoidance potential are made.

Good Practices for the Collection of Biodiversity Baseline Data, prepared for the Multilateral Financing Institutions Biodiversity Working Group and CSBI, summarises good practices for biodiversity baseline studies that allow biodiversity to be included effectively and fully in impact assessment and related management plans.

The Good Practice for Biodiversity Inclusive Impact Assessment and Management Planning is a supplementary guidance document that complements reports and guidance on impact assessment published by a broad range of actors from government, industry and NGO sectors. It takes a specific look at biodiversity risks and their respective management requirements, suggesting that projects should tailor the level of rigour applied in impact assessment and management planning according to the sensitivity of the site and the potential impact of the project.

The CSBI Timeline Tool assists professional planning extractive projects in coordinating project development calendars, biodiversity impact assessment and management schedules, and financial timelines milestones. It has been designed to present a roadmap to identify milestones and key interdependencies between project development schedules, financing timelines and the actions required to effectively apply the mitigation hierarchy. Whilst not being proscriptive, it recognises the operational challenges associated with identifying and mitigating biodiversity impacts.

Appendix 4: Establishing a robust marine BES baseline

The rationale for conducting a robust and integrated biodiversity and ecosystem services (BES) baseline and general good practices in developing a BES baseline are summarized in this Appendix. A range of guidance documents have been developed to support the preparation of a biodiversity and/or ecosystem service baseline and a selection of these are featured in Box 1. The guidance provided in this Appendix is therefore intended to be supplementary to information available in other existing resources and users of this GPG are advised to read this appendix alongside other recommended guidance, in particular:

- *Good Practices for the Collection of Biodiversity Baseline Data (Gullison et al. 2015[1])*
- *Biodiversity and Ecosystem Services Fundamentals: Guidance Document for the Oil and Gas Industry (IPIECA & IOGP 2016[2]).*

In this Appendix, guidance focuses on i) key considerations specific to the marine environment, ii) use of an ecosystem-based approach to determining BES baseline conditions, and iii) early integration of ecosystem services. Case studies illustrating good practices in marine BES baseline studies are presented.

What is a BES baseline and why does it matter?

A biodiversity and ecosystem services (BES) baseline is designed to provide information on the BES values and sensitivities occurring at a site and their current condition, trends and uses[1]. It describes the status of BES in and around the project area and wider coastal and marine environment and it is against this baseline that potential BES-related risks and impacts resulting from a project are assessed.

A robust understanding of the BES baseline provides the foundation for the rigorous application of the mitigation hierarchy and the design and implementation of BES management and monitoring[1,2]. Baseline studies are conducted before a project commences and feed into an impact assessment; however, studies may also be conducted at other times and for different reasons throughout a project's life cycle.

The importance of undertaking marine BES baseline studies cannot be underestimated in the marine realm. It is only by investing in developing baselines of the appropriate scale, scope and depth that potential BES-related risks, impacts and opportunities can be properly anticipated, mitigated and monitored. Over the long-term, effective BES baselines can support cost-effective mitigation and may prevent costly delays and difficulties relating to BES-related issues later in project development[1,2]. Baseline studies by oil and gas companies have further made an important contribution to our understanding of the marine realm and so have a wider societal value.

Box 1: Why integrate ecosystem services into marine baseline studies?

Until recently ecosystem services have received limited attention in baseline studies, often only considered after the Environmental and Social Impact Assessment (ESIA) has been completed and gaps identified. Yet early integration of ecosystem services in marine baseline assessments (e.g. as an extension of biodiversity and social baselines and integral part of the ESIA process) can:

- Improve understanding of relationships between the environment, biodiversity and people.
- Enable a more integrated and holistic approach to impact identification, mitigation and management.
- Support the early identification of ecosystem service dependencies, risks and impacts and enable preventative action to avoid and minimise adverse impacts on ecosystem services. This can help to avoid conflict with local stakeholders and rights holders and support development of positive relationships with users of the seascape.
- Allow for links to be made between information from the environmental baseline and information from social baselines to produce tangible and realistic management activities and indicators for monitoring and evaluation[3].
- Inform stakeholder engagement processes (e.g. for the social baseline) and promote efficiencies in the way in which information is gathered, interpreted and validated with stakeholder input.

The development of more sophisticated and tested methodologies for undertaking ecosystem service assessments and a growing evidence base on the relationships between biodiversity, ecosystem function and ecosystem services is facilitating the early integration of ecosystem services in baseline studies. The business value gained through the early assessment of ecosystem services is increasingly being realised by some companies (see Box 10).

Good practices for a BES baseline

Good practices in the development of the BES baseline include:

- The collection of BES baseline information early in the project cycle.
- Ensuring the BES baseline and all assessments conducted as part of the baseline are the appropriate scale, scope and depth.
- Application of a precautionary approach (see Principle 9, GPG Section 2).
- An iterative approach that:
    - progresses from high-level, coarse resolution information to more detailed information that is validated on the ground.
    - responds to information as it arises through baseline studies and meets the evolving needs of the environmental assessment.
- Use of best available and the most up to date information and data.
- Bringing together the right combination of skills, expertise and approaches at each stage of developing the BES baseline (e.g. from ecology, marine science, social science, social anthropology, etc.).
- Effective coordination, communication and information sharing across functions (e.g. between an operation's social and environmental teams).
- Early identification and involvement of stakeholders, particularly those dependent on BES.
- Integration of traditional ecological knowledge, where applicable, e.g. to inform understanding of past and current trends and relationships between species, ecosystems and ecosystem services.
- Consideration of the wider seascape context to help: understand how ecological features are connected over space and time; identify ecosystem service supply areas, the location of beneficiaries, and the flows of services across the sea- and landscape; and identify other stressors in the seascape and potential mitigation opportunities (e.g. possible alternatives for siting infrastructure).
- Explicit recognition of uncertainties, gaps in information and limitations of available methods for understanding BES baseline conditions.

Box 2: Guidance available to support good practice in developing a BES baseline

IPIECA & IOGP (2016) ***Biodiversity and Ecosystem Services Fundamentals***. ***Guidance Document for the Oil and Gas Industry***. This guidance supports the management of BES impacts, dependencies, risks and opportunities in the oil and gas sector. Chapter 3 is dedicated to the integration of BES into baseline studies to ensure baseline conditions provides the necessary foundation for assessing, avoiding and/or managing potential BES impacts, risks and opportunities.

Gullison, R.E., J. Hardner, S. Anstee, M. Meyer (2015) ***Good Practices for the Collection of Biodiversity Baseline Data***. Prepared for the Multilateral Financing Institutions Biodiversity Working Group & Cross-Sector Biodiversity Initiative. This guidance collates and summarises good practices for biodiversity baseline studies that allow biodiversity to be included effectively and fully in impact assessment and related management plans.

Geneletti, D. (2016) ***Handbook on Biodiversity and Ecosystem Services in Impact Assessment***. Edward Elgar Publishing: Cheltenham UK / Northampton MA USA. This handbook is designed for practitioners and researchers and provides a critical analysis of some of the latest research and practice in BES-inclusive impact assessment.

EBI (2003) ***Integrating Biodiversity into Environmental and Social Impact Assessment Processes***. EBI's guidance document is designed to support the integration of biodiversity into an ESIA. As such, it does not provide a review of the ESIA process, but instead focuses on the steps and actions necessary to accomplish the proper integration of biodiversity. Suggestions are made for the integration of biodiversity. Suggestions are made for the integration of biodiversity at seven stages including identification of alternatives, screening, scoping, baseline establishment, impact analysis, development of mitigation options and implementation.

IAIA (2005) ***Biodiversity in Impact Assessment.*** Special Publication Series No. 3. This IAIA guidance document is designed to help practitioners to integrate biodiversity into impact assessment (IA), decision-makers to commission and review IAs, and other stakeholders to ensure their biodiversity interests are addressed in development planning. The principles presented are intended to promote "biodiversity-inclusive" impact assessment.

CIEEM (2016) ***Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal, 2nd edition.*** Chartered Institute of Ecology and Environmental Management, Winchester, UK. CIEEM's Guidelines for Ecological Impact Assessment are designed to promote good practice, provide a scientifically rigorous and transparent approach to Ecological Impact Assessment (EcIA) for terrestrial, fresh water and coastal ecosystems. They present a common framework to EcIA in order to promote better communication and closer cooperation between ecologists and decision-makers involved in EcIA.

World Resources Institute [WRI] (2013) ***Corporate Ecosystem Services Review, Weaving Ecosystem Services into Impact Assessment. A Step-By-Step Method.*** (Version 1.0) and ***Weaving Ecosystem Services into Impact Assessment. Technical Appendix*** (Version 1.0)**.** WRI's guidance introduces the Ecosystem Services Review for Impact Assessment, a six-step method to address project impacts and dependencies on ecosystem services as part of the environmental and social impact assessment process (see also Boxes 9 and 10 below which highlights how the ESR approach has been adapted and applied in the context of a marine oil and gas operation). The steps build on assessments routinely conducted by social and environmental practitioners to better reflect the interdependence between project, ecosystems, ecosystem services, and people.

Conducting a marine BES baseline

The steps involved in developing a BES baseline for a project will vary according to the BES values and sensitivities, as well as regulatory, lender (for externally financed projects) and corporate requirements[2]. The general steps involved in a BES baseline study – from high-level screening assessments to more detailed and finer scale assessments in the field – are summarised below and in Figure 1. These are described in more detail in Gullison et al. (2015) *Good Practices for the Collection of Biodiversity Baseline Data*[1]. Here, we focus on: i) specific considerations when establishing a BES baseline in the marine realm; ii) use of an ecological approach to determining BES baseline conditions, and iii) the early integration of ecosystem services into the baseline. GPG users are advised to consult experts and other available resources for detailed guidance and support (see Box 2, above).

Figure 1: Generalised steps for establishing a marine BES baseline

Step 1 – High-level screening

Screening assessments are used to capture a relatively coarse level of information about BES in the area of interest. Screening is used to inform, and will be augmented by, further detailed assessments required to establish baseline conditions and support mitigation planning[2]. Screening is typically conducted over a broad area and can help inform delineation of the area that will be subject to further scoping and field assessment.

The screening process helps to provide a high-level picture of BES in the area including potentially sensitive, high value biodiversity components (e.g. threatened or restricted range species or ecosystems; keystone species; areas essential for ecosystem function or species persistence such as ecological corridors or important seasonal foraging areas) and potential ecosystem services. The process provides an early alert of potential BES risks, threats and values, their magnitude and the extent of BES mitigation planning and management that may be required[2].

High-level screening is typically undertaken through desk-based assessment drawing on existing, available data and information (see Box 3). Expert consultation, initial stakeholder engagement and field reconnaissance may also be undertaken to inform the screening process and may be particularly important in the early identification of BES dependencies.

Box 3: Information sources available to support BES screening and scoping stages:

Global databases for ecosystems, habitats, species, protected areas and other features provide a useful starting point for high level screening by highlighting areas that may be important for biodiversity and may overlap with or be in close proximity to a proposed project site (e.g. global datasets accessible through the Integrated Biodiversity Assessment Tool (IBAT)[i] such as the IUCN Red List of Threatened Species, Key Biodiversity Areas and Protected Planet/The World Database on Protected Areas). There is currently no equivalent global database or standard set of criteria for identifying when and to what degree ecosystem service provision in a given area is at risk[4]. However, a threat assessment framework for ecosystem services has recently been put forward by Maron et al. (2017). The framework considers the states and trends of ecosystem service supply and demand and could provide the basis ecosystem service threat assessments at global, national or regional scales in future[4].

Whilst much of the ocean is yet to be mapped and surveyed, information and data sources are available and may be helpful in building a preliminary picture of marine BES features in the area of interest. For example:

- Census of Marine Life
- Global Biodiversity Information System
- Global Information System on Fishes
- UNEP-WCMC Ocean Data Viewer

Note that some websites have commercial use restrictions and some should be accessed through the Integrated Biodiversity Assessment Tool (IBAT)[i].

When utilising global and regional databases caution must be exercised as datasets often come from a wide variety of sources, are created with different purposes in mind, and may be presented in a range of formats. Marine biodiversity data also suffers from spatial and temporal biases and the accuracy and resolution can be highly variable. This is particularly true with habitat distribution maps and species datasets for which the resolution of mapping may be coarse and based on outdated and/or incomplete information. Similar issues have emerged with the mapping of biodiversity hotspots in which the coarse resolution of most datasets masks the small-scale patterns associated with coastal habitats or deep water features such as seamounts[5].

The highly dynamic nature of the marine environment and potential for habitat quality and extent, species composition and key supporting ecological processes to shift due to a variety of factors are also important considerations when using global databases. It is therefore necessary to cast a wide net and ensure that regional, national and local data sources are explored fully. Finer resolution data relevant to the local area of operation will be needed in most cases.

Regional, national and subnational information can contribute valuable information to desktop screening and scoping processes. Sources of information may include:

Interactive online mapping and decision support tools have been developed that can act as high-level screening tools. For example:

i IBAT and some other websites incur a cost for commercial use

Regional or national data portals (e.g. Caribbean[i], Europe[ii], Australia[iii] and the US[iv,v]) can provide information to support seascape assessments and marine baseline studies. Some are specific to the marine environment. For example, in European waters the EMODnet habitat data portal[ii] provides important datasets, including both broad-scale modelled marine habitat maps and a catalogue of habitat maps produced by surveys. Under the same initiative, detailed bathymetric data can be found in addition to consistent European coverage bathymetric DEM, as well as geological, biological, and physical parameter datasets.

Interactive online mapping and decision support tools have been developed that can act as high-level screening tools. For example:

- The Australian federal government has developed the 'Protected Matters Search Tool' which allows the user to identify biodiversity issues relevant to regulatory frameworks and policy. In this case whether a chosen site may interact with eight conservation issues including World Heritage and other protected areas, threatened communities and threatened or migratory species.
- North Sea Interactive developed a decision support tool that translated marine environmental data into an interactive mapping product for the offshore oil and gas industry[vi]. The objectives of the project were achieved through the integration of the North Sea Benthos database with NERC's regional North Sea marine sediment data and layers of modelled hydrodynamics (NOC). Aligning the biological, chemical, geological and hydrodynamic datasets in a single GIS product that provided the oil industry and government regulators (e.g. through the Scottish Government's Interactive Planning Tool: the National Marine Plan Interactive[vii]) with a practical means of accessing this important archive of environmental data. The data is now available to all environmental data managers with an interest in offshore industries; with a particular use in ESIAs, permits and other seabed analysis and environmental monitoring by the oil and gas industry.

The assessment and mapping of marine ecosystem services has also become a growing area of focus for countries and regions around the world and ecosystem service assessments may be available for some regions, countries and seascapes. It is important to review studies critically – taking into consideration their approach, aim and rationale, type of ecosystem service assessed, spatial and temporal scale, and source of information - and determine their relevance and usefulness for the BES baseline.

With any regional or national data repository, it will be necessary to understand limitations and gaps in available data. For example, data is often provided at a broad scale or coarse resolution that would be insufficient on its own to fulfil the needs and requirements of a seascape or marine BES baseline assessment. Baseline screening and scoping processes help identify such limitations and the gaps that will need to be addressed through baseline studies.

Other key information sources include:

- National Ecosystem Assessments (where available) and the National Biodiversity Strategic Action Plan are also good places to begin as well as any sub-national action plans, lists of threatened (and candidate) species and ecosystems or sites, species distributions, and action plans for certain species or habitats.
- National Development Plans, poverty and wellbeing assessments, livelihoods studies, census data and sector specific databases, strategies and management plans (e.g. water, fisheries, tourism) may be helpful in the preliminary identification of potential ecosystem service dependencies and impacts.
- Marine protected area maps and management plans, seascape level assessments and systematic conservation plans.
- Peer reviewed literature
- Project reports and unpublished studies
- Site, ecosystem or seascape conservation and management plans
- Strategic Environmental Assessments and/or Cumulative Impact Assessments

i http://atlas.caribbeanmarineatlas.net

ii http://www.emodnet.eu

iii http://maps.eatlas.org.au

iv /https://coastalmap.marine.usgs.gov/FlexWeb/national/usseabed

v http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm

vi www.northseainteractive.hw.ac.uk

vii http://www.gov.scot/Topics/marine/seamanagement/nmpihome

- Biodiversity baseline studies and ESIAs for other development projects
- Other components of the ESIA (social, water resources, greenhouse gas assessments etc.). Where the ecosystem service component of the BES baseline is being undertaken after other baseline studies and impact assessment work, relevant data may already exist. Making the links between existing data and ecosystem service supply and demand will be crucial for the effective integration of ecosystem services risks, opportunities and mitigation actions into the project ESIA moving forward.

It will be necessary to determine the quality and accuracy of reports and data, particularly where these have not been subject to peer review, and findings must be interpreted and utilised appropriately.

Stakeholder and expert engagement

- Consultation with experts and stakeholders is a vital component of gathering information on BES and identifying BES values. It can help to expand knowledge, fill information gaps, assist in identifying surrogates or proxies where data is of poor quality or unavailable.
- Early engagement with stakeholders is especially important in the preliminary identification of BES dependencies[2,6].
- Engaging a range of experts will be important to foster the breadth and depth of input required. Relevant experts may include traditional knowledge holders, conservation and development organisations, governmental or other relevant authorities, and academic or other scientific institutions, as well as individual experts (including species specialists, marine ecologists, fisheries scientists, social anthropologists, livelihoods and ecosystem service specialists, etc.)
- See also GPG Section 2 (Principle 7) and references therein for further guidance to support best practice stakeholder engagement

Step 2 - Delineate the baseline study area

Defining the extent of the study area is an important step in baseline design that will influence the amount of information and understanding gathered on the status of BES. A precautionary approach is recommended that encompasses the area within which a project's direct, indirect and cumulative impacts to BES are predicted to occur.

The process of defining the study area should take into consideration:

- the geographic area of anticipated project activities, operational infrastructure and associated facilities constructed as a result of the project, and associated impacts (also known as the project area of influence)
- impacts of non-project activities in the surrounding area that have been caused or stimulated by the project (e.g. changes in economic or social patterns catalysed by the project's presence) and that can have significant adverse impacts for BES (e.g. by enabling access to previously inaccessible areas)
- distribution of biodiversity values (e.g. species and population distributions, habitat extent, dispersal or migration corridors, known foraging or breeding areas, location of conservation areas etc.)
- ecologically meaningful boundaries that take into account spatial and temporal components of species and ecosystems and the relationships between them. Where ecological boundaries are difficult to define, the use of a buffer may be appropriate. The buffer area should be determined by the level of impact and the sensitivities of biodiversity values to those impacts.
- the area of biophysical supply of ecosystem services, taking into account the spatial distance between the supply area and beneficiaries (where applicable), and the influence of formal (laws, regulations) and informal (norms, cultural taboos) institutions on beneficiary access to ES supply regions[7].
- spatial and temporal components (e.g. seasonal patterns of habitat use by particular species or the access and use ecosystem services by different stakeholders at different times of year). The extent of the assessment area should allow for variability in space and time to be captured.
- the wider seascape context to allow for the inclusion of potential cumulative or compounding impacts across the ecosystem (e.g. related to other developments and activities, or underlying climatic and environmental trends). In regions where little is known about marine BES, wider seascape surveys may be necessary to further refine the study area boundary and determine the likely significance of project impacts.

It should be noted that:

- Identification of beneficiary groups is an important early step in the ecosystem service component of the baseline, with specific spatial and temporal extents for each service determined based on how beneficiaries interact with their environment.

- The extent of the assessment area defined for assessing ecosystem services can differ, and may be larger, than the area for the biodiversity baseline. For example, it may need to consider ecosystem service flow to distant locations and beneficiaries and the distance at which the project activities may impact the availability, access to and functionality of ecosystem services.
- When the ecosystem service and biodiversity impact assessments are undertaken jointly, the spatial extent for the baseline study area will be the combined maximum area considering both the ecosystem services and biodiversity assessment areas[7]. Note that not all areas within this entire study area will necessarily be subject to the same depth of assessment.
- A BES baseline is usually an iterative process, as new data becomes available or as project activities and plans change. This means the scope and depth of the BES baseline study may vary across the study area, and indeed the delineation of the study area may change, too.
- The rationale behind any study area extent should be transparently documented to understand the caveats of what is and isn't considered.

Step 3 - Scope the BES baseline study

The scope of the baseline study refers to the BES values and related environmental characteristics that will be included in the ESIA. During scoping existing datasets and gaps are identified, and the scope, scale and depth of the baseline assessment (Step 4) determined. The scope may also include methodologies that should be used, the spatial and temporal scale of the study, and definition of key stakeholders (adapted from Gullison et al. 2015[1]).

BES are usually evaluated through a combination of desk-based assessment, biophysical, socioeconomic and/or cultural surveys, consultation with experts, and stakeholder engagement. It is important to stress here the iterative nature of this process, particularly in the marine realm, where data availability can be highly variable depending on project location. Early investment in gathering available regional and local data, preliminary field surveys and engagement with stakeholders and experts is often essential in further informing and refining the scope of the BES baseline study.

The baseline scope should consider the following biological and physical features and variables:

1. **Physical and biophysical conditions** including water quality, wind, precipitation and air quality, tides, currents, waves, and salinity and temperature stratification. Characterization of the water column will include assessment of dissolved oxygen, nutrients, and chemical composition. Benthic habitat elements include reference to the sea bed structure including surficial and sub-surface sediments. Results should be presented with comparisons to internationally recognized standards.

2. **Habitats** are important in their own right but can also serve as proxies for the ecological processes that produce them, the species that reside within them, and the ecosystem services that the habitats help to provide. It is important that a baseline study provides information on habitats at appropriate scale/s, from site level (e.g. type, condition or quality) to seascape level (e.g. distribution across the baseline study area and wider seascape, connectivity, fragmentation and patchiness of habitats).

3. **Species**, including plankton, benthos, forage fish, target fish and shellfish species, shore and sea birds, and marine mammals, as well as any threatened, protected and/or keystone species or species that directly or indirectly contribute to the provision of ecosystem services such as food and coastal protection. Consultation with experts is recommended to draw up the list of taxonomic groups to be included, focusing on those species and life stages that may be most affected by the project and associated facilities. Specialist studies will be needed for species of high biodiversity value (e.g. species that are threatened, have a restricted range, are migratory or congregatory species, are keystone species, considered a conservation priority nationally or by experts, or play a key role in ecosystem function and/or the provision of priority ecosystem service/s).

4. **Ecological patterns and processes** vital for maintaining the viability of important biodiversity values and the continued delivery of many ecosystem services. It is important to take an ecosystem approach using sound ecological information that considers the ecological patterns (e.g. species abundance and richness, habitat heterogeneity) and processes or functions (e.g. predator-prey interactions in a food web, connectivity and dispersal). Ecological patterns and processes are dynamic in their variability and responses to change, often influenced by human-induced activities or abiotic and climatic changes.

5. **Oceanographic features,** such as submarine canyons, seamounts and hydrothermal vents, are important in their own right and as proxies for other BES values. For example:

    - S*ubmarine canyons* with their steep slopes and varied topography result in high diversity of habitats and species in small spatial scales.
    - *Seamounts* are steep-sided underwater volcanoes that serve as hotspots of pelagic biodiversity[8] and attract aggregations of seabirds, sharks, tuna, billfish, sea turtles and marine mammals. Seamount ecosystems have

supported small-scale artisanal fisheries from oceanic island chains for generations and serve as reservoirs of abundance and biodiversity[5].

- *Hydrothermal vents*[ii] *and cold seeps*[iii]. The unusual chemistry in these hot and cold, mineral rich water and unique ecological processes have enabled the evolution of unique biological communities[9].

6. **Ecosystem services** (see GPG Sections 3.4 and 3.5), including services and associated beneficiaries that the operation may impact and those services that it depends upon for its operations. It is important to consider who depends on services provided by which ecosystems or habitats and to what extent (i.e. the **demand** for an ecosystem service), where these are being produced (i.e. the **source** or **supply**), how an ecosystem service **flows** from its source to a beneficiary (e.g. migratory fish movements to fishing areas, access to coastal tidal zones for harvesting), and the **importance** of those ecosystem services to beneficiaries, acknowledging that some ecosystem services cannot be replaced or substituted. The extent to which the supply of an ecosystem service meets demand (adequacy) and in the future (sustainability) needs to be considered[4].

7. **Protected areas**[iv] **and other sites important for biodiversity** including UNESCO World Heritage Sites[v], Biosphere Reserves, Ramsar sites, and national or regional designations such as Specially Protected Areas of Mediterranean Importance and Natura 2000 should be considered as well as areas protected at national and local level (e.g. indigenous peoples' and community conserved areas[vi], and national parks). Key Biodiversity Areas (KBAs)[vii], Alliance for Zero Extinction (AZE) Sites, and Ecologically or Biologically Significant Marine Areas (EBSA) and any other areas identified by a broad set of stakeholders or governments as a conservation priority. These sites may overlap wholly or partly with existing protected area boundaries but may also fall outside of protected areas and be subject to other management approaches.

Gap analysis and developing the Terms of Reference for field work:

Once all available existing information is assembled, it needs to be examined to identify any significant data gaps relating to sensitive BES features. In the marine environment, there should be an expectation that gaps in knowledge and information may be extensive and thus the requirement for field studies is likely to be high. Gaps and limitations in available information may relate to insufficient data on certain taxa and ecosystems, inadequate spatial resolution or scope, limited temporal/seasonally relevant information, patchy data, etc.

Terms of Reference (ToR) for field surveys will need to be developed, building on the findings of the desktop assessment, field reconnaissance (where applicable), stakeholder and expert input, and the gap analysis. The ToR should include requirements for the scientifically robust collection of primary data relating to biodiversity, ecological and chemical-physical features in the area of interest and clearly outline expected deliverables. Where there is limited information upon which to determine BES values and sensitivities (as will often be the case in the marine realm owing to a paucity of data and limitations in our understanding of BES sensitivities) a precautionary approach should be adopted.

Step 4 - BES baseline field assessment and specific considerations in marine environments

The field-based assessment of BES values aims to address identified gaps and verify information gathered through screening and scoping (Steps 1 - 3). Given current limitations in knowledge and available information on marine BES, it is likely that field-based assessments will be required at most or all marine oil and gas operations. The scope, scale and depth of field-based assessment will depend on the type of project, scale and scope of likely impacts and the sensitivity of potentially affected BES values and the wider marine system.

For oil and gas projects operating in sensitive BES seascapes, the field-based assessment is likely to be extensive and detailed, and represent a large investment of time and resources. BES research at sea is much costlier than on land as there is a limited pool of organisations and experts with the necessary knowledge and capability, whilst survey instruments need to be fit for the

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ii Hydrothermal vents are found where deep cold ocean waters seeping into the oceanic crust come into contact with molten lava or hot rocks closer to the mantle. The resulting super-heated water dissolves minerals from the rocks it has passed through. When injected into the near-freezing water on the ocean floor the minerals precipitate, forming rock formations and chimneys.

iii Cold seeps occur where water only a few degrees above ambient temperatures carries hydrogen sulphide, methane and hydrocarbons from the basement rock to the sediment surface.

iv A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of biodiversity with associated ecosystem services and cultural values (IUCN Definition 2008).

v As of 2013, there were 46 sites included in the World Heritage List that had been designated for primarily for their marine natural features of Outstanding Universal Value and a further 25 other natural and mixed World Heritage Sites contained marine areas or features of marine interest.

vi For information on ICCAs see: http://www.iccaconsortium.org/

vii A global standard for the identification of Key Biodiversity Areas has been published: IUCN (2016) A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition. Gland, Switzerland: IUCN. Available from: https://portals.iucn.org/library/sites/library/files/documents/Rep-2016-005.pdf environment, i.e. resist extreme pressures and the corrosion caused by salt. In addition, because water is not as transparent as air, it is not possible to rely on satellite imagery to 'see' clearly what happens below the sea surface. Costs for baseline field assessment should be factored into budgeting early in the project planning cycle and contingency funds made available to cover the costs of additional studies should they be necessary.

The results of field assessments may identify the need for further field surveys (e.g. where additional BES values and/or risks are detected) to support a thorough baseline study. The baseline study area may also need to be revisited and adjusted to take into account new findings and ensure that it remains ecologically relevant.

Existing guidance, ***Good Practices for the Collection of Biodiversity Baseline Data***[1]***,*** provides an overview of key issues associated with the design of field-based assessments, choice of methodologies, general good practices and methodological considerations for surveying and measuring different types of biodiversity values; methodological references are also available[1]. The IPIECA-IOGP 2017 guidance, ***Biodiversity and Ecosystem Service Fundamentals***[2]***,*** further provides guidance specific to the oil and gas sector.

Here, we highlight a number of key considerations specific to the BES baseline assessment in the marine environment. This includes:

- Marine habitat mapping
- Marine survey methods
- Characterisation of marine biodiversity
- Integration of ecosystem services

Marine habitat mapping

Preparing a high resolution (i.e. at least 50 x 50 m) habitat map as early as possible in the baseline schedule is good practice, and it is recommended that its preparation precede the design of field surveys for other types of biodiversity values wherever possible. This will inform field survey design for other BES components, particularly where habitat is used as a proxy for other biodiversity values (e.g. certain species for which specific range data is not known but for which habitat associations have been determined).

Marine habitats can be mapped using different approaches (see Box 4) and through direct and indirect methods (see also Box 6). Methods will often differ from those employed in the terrestrial realm. Direct mapping through observation (e.g. delineating seagrass beds in shallow waters by snorkeling or scuba diving) may be feasible over small, shallow areas. Indirect methods applied commonly in terrestrial settings, such as passive optical remote sensing, require advanced techniques to account for the attenuating effects of the water column and are restricted to shallow and sufficiently clear waters. Where indirect mapping is employed (e.g. using a combination of satellite, acoustics) it should include significant ground truthing (not just a few points) and preferably some form of accuracy assessment (e.g. through additional ground truthing).

A habitat map created using indirect methods would integrate multiple sources of data (bathymetry, other derivatives of bathymetry such as slope, a measure of hardness (reflectivity / amplitude) and potentially other variables (e.g. temperature, food supply etc.). Habitat maps should also include maps of confidence (i.e. how confident we are that this pixel represents what we say it does) - this often has high spatial variability.

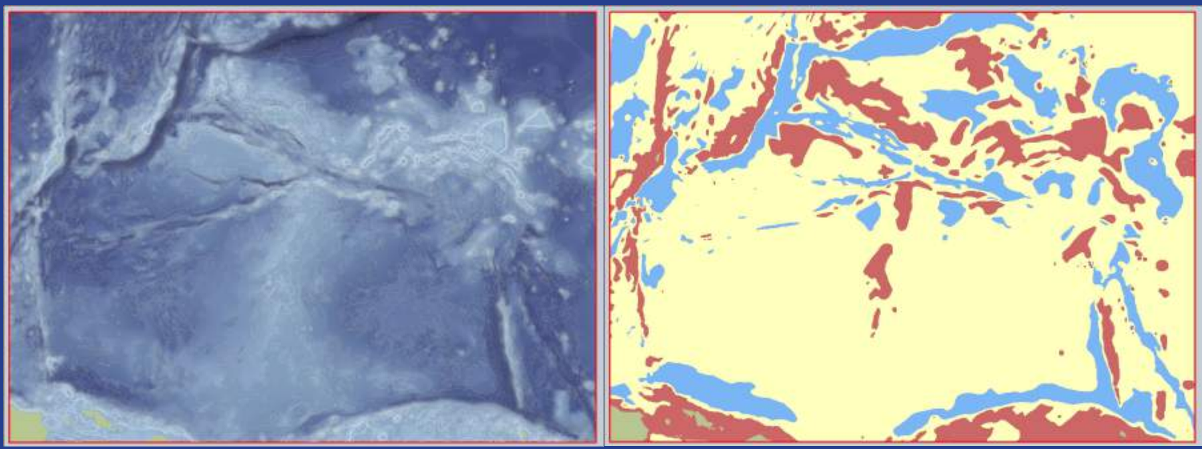
Box 4: Habitat mapping approaches: top-down and bottom-up

Habitat mapping (both in the marine and terrestrial environment) can be characterized by two approaches: top-down and bottom-up[10]. Broadly speaking top-down refers to the construction of habitat mapping units on the basis of differences between physical, geological and environmental conditions (at the seabed, but also within the water column). Parameters such as substrate type, depth, light level, wave and current energy and salinity regimes may be mapped via a range of methods, and thresholds then imposed on these to delineate habitats, through ***a priori*** knowledge of the habitats in question[11]. In a bottom-up approach, samples from biological communities are analysed statistically with respect to the environmental conditions and grouped together into classes that share correlations with these parameters (whether or not there is a true preference for these conditions).

These two approaches are also reflected in habitat classification systems. For example, the European Nature Information System (EUNIS) habitat classification[i], widely used across Europe and particularly in the marine context, tries to rationalize these two approaches – distinguished at its highest levels by larger scale physiographic differences (e.g. shallow versus deep, high energy versus low energy, mud versus sand versus rock, etc.), with more detailed habitats, dictated by the biological communities found within them, nested at the lower levels of the classification within the high-level habitats.

See: https://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification i

Box 5: Using bathymetry to address data deficiencies



Where information on marine BES is limited, e.g. in deeper water, it may be necessary to use other information sources to predict or identify potential areas of high BES value. Bathymetry (see below, left) is a good starting point, providing a topographic map of the ocean floor. Further analysis can help identify features of interest: geomorphological variables such as Bathymetric Position Index (BPI; see below, right) can be combined to identify features at different scales by looking at the depth of a given location relative to the surrounding depth. At broad scales, it is possible to define shelf-breaks and slopes and plateaus. At fine scales, it may be possible to pick out areas such as reef, sand ripples, canyons and seamounts. These features may be used to direct further research to specific locations. Where more accurate bathymetry is available, it may be possible to predict the presence of certain marine species, communities or habitats based upon established relationships with geomorphological features.

Source: The GEBCO_2014 Grid, version 20141103, http://www.gebco.net

It is recognised that the logistical and technical difficulties associated with penetrating a large mass of dynamic water for marine habitat mapping can be considerable and marine surveys can incur significant cost. Wherever possible, it makes sense to maximise efficiencies in terms of shared boat and equipment time, and extend the value of mapping work undertaken as part of the baseline. For example, bathymetric maps can be used to produce a substrate map that would support habitat mapping for that seascape (see also Box 5).

Marine survey methods

Survey methods for each element of the biodiversity baseline must be carefully designed by marine experts using a statistically reliable sampling scheme that can estimate inter-seasonal and inter-annual variation using a full range of sampling gear. Survey methods should be designed to allow for replication as part of longer term monitoring by the operation.

Marine biodiversity experts will play an important role in undertaking and/or overseeing marine surveys, reviewing work undertaken and supporting data analysis and interpretation. The technology and approaches to support the characterisation and monitoring of the marine environment is an evolving field (see, for example, Box 6) with new advances emerging and available for application. Box 7 provides an example of a good practice baseline study in deep water environments. In all cases, it will be essential that marine oil and gas operations seek advice and apply the best available technology and methods possible to establish baseline BES conditions.

Box 6: Remote sensing survey methods in shallow and deep water environments

In shallow waters, optical remote sensing methods may be employed where water clarity is sufficient (the limits for mapping, e.g. coral reefs and seagrass, typically found in clear waters is usually around 25m, but varies greatly according to turbidity) and the spectral signatures of the habitats of interest are adequately distinct. The spectral configuration of sensor is crucial in this regard; as well as spatial resolution (consideration needs to be given to the minimum mapping unit[i], appropriate to the habitats in question and the wider seascape approach requirements), temporal, spectral and radiometric resolution all have a bearing on which sensor and platform may be used. In some cases, a moderate resolution satellite such as Landsat 8 may be the best choice, in others a coarse resolution sensor such as MERIS which is well-suited to water applications may be best, or a very high resolution imagery such as World-View 2 may be necessary. In the case of the latter especially, image availability may be a constraining issue, in addition to cost.

For deeper waters, acoustic remote sensing techniques (in tandem with ***in situ*** sampling) are the usual alternatives, most often sidescan sonar systems (SSS), and multi-beam echo sounders (MBES). There are three main strategies in methods applied to the data collected via these techniques: 1) Abiotic surrogate mapping; 2) Assemble first, predict later (unsupervised classification); 3) Predict first, assemble later (supervised classification)[12].

Sidescan sonar is a category of sonar system that is used to efficiently create an image of large areas of the sea floor. It works by emitting conical or fan-shaped beam across the vessel's trackline and listening to all echoes returned, so providing an 'image' of the seafloor. These images may be mosaiced to cover a region and image processing techniques used to discriminate similar patches of seafloor. Multibeam sonars are the most complex of the systems, sending out a fan shaped beam across the vessels track and sampling it in many narrowly focussed beams to precisely measure bathymetry and provide information on seabed character from the nature of each beam's backscatter. Sidescan and multibeam can be used to provide full spatial coverage of a targeted area, they can typically sample out to 3-7 time the water depth from the vessels track line[13].

i Size of the smallest feature that needs to or can be distinguished with boundaries on a map. For example, if a patch reef of 5m diameter is important to distinguish, 30m resolution imagery is clearly insufficient.

Box 7: An example of a good environmental baseline study in a deep-water environment

An environmental baseline study should provide a comprehensive understanding of the physical, chemical, and biological environment of an area prior to development activities. In the deep sea this is challenging because there is very little background information for most areas and access for assessment is very expensive. The problems for deep-water is that 35-95% of bathyal/abyssal macrofaunal species are new to science[14,15,16,17] densities and biomass are typically relatively low[18] and biodiversity is high[19] so large or numerous samples need to be taken to properly characterise areas, particularly if these data are used for impact assessment. Furthermore, development areas in the deep sea are often large and some areas, particularly on the continental margins, are environmentally heterogeneous[20]. The environmental problems are compounded by difficulties in sampling, with remote locations, gear being less effective[21] and large depths requiring often several hours to get a single sample – leading to requirements for more expensive ships being used for longer.

Deep sea surveys need to be carefully designed, using best available information prior to going to sea. This typically involves using acoustic data (multibeam bathymetry, side-scan sonar or initial seismic returns) to determine environmental heterogeneity with bathymetry and seabed hardness (amplitude / backscatter) data. This information can be used to delineate potentially similar areas and design a stratified random sampling approach. Multiple replicate samples should be taken at random in each stratum. Additional samples can be targeted at features of interest, potentially including development sites. The number of samples should be planned based on best available information on species densities and diversities in the study area.

In some areas with very low faunal densities, such as the eastern Mediterranean, it may be necessary to base biological assessment on smaller and more numerous faunal groups e.g. meiofauna, rather than using typical macrofaunal assessment. It may also be necessary to obtain significant amounts of sediment for some chemical analyses e.g. 50g of sediment may be required for assessment of hydrocarbon contamination[22], particularly as contamination loads may be low in deep-water baseline samples. It is worth considering multiple assessment mechanisms, including sediment sampling, photography, acoustic surveying, sensor-based measurements to optimise the amount of data obtained and the appropriateness of the data for the environments under investigation. It is also important to standardise methodologies and ensure that all data are comparable between surveys, particularly if the data will be used for monitoring.

Data acquisition should be done with great care in deep-sea environments. Deep-sea organisms are often fragile suffering greatly from mechanical damage and temperature changes. Samples should be processed (particularly sieved) very carefully, avoiding as much temperature change as possible (particularly in tropical areas) and preserved quickly. Sieving needs to be done gently to retain good quality specimens, smaller (e.g. 250µm sieves) may need to be used in addition to more standard sieve sizes (e.g. 500µm). Many samples have been rendered unusable by poor sample processing. For some techniques, specialist equipment is likely to be required to access deep-sea environments. This should be specified in advance. In the case of imagery, it is recommended that quantitative data can be obtained from imagery, requiring many, good quality, scalable images, usually requiring the use of parallel laser scalers.

Analysis of data, particularly biological data from the deep sea requires specialist expertise. This cannot be easily assessed in schemes such as the National Marine Biological Analytical Quality Control Scheme (NMBAQC), which is designed for shallow water assessment. It is also important for comparison of data that all consultancies use the same names for undescribed species, this requires use and exchange of samples in reference collections. Photographic guides to morphospecies should be developed with representative images, detailed descriptions (that allow discrimination of all species observed) and links to specimens / genetic material if available. This is particularly vital for monitoring surveys where comparisons are made.

Reporting should be thorough and most critically the methods, data (raw and processed) and comprehensive metadata should be provided in a format that facilitates future analysis. GIS data are preferred with attached metadata that conform to appropriate standards.

Characterisation of marine biodiversity

It is important that baseline data goes beyond simple presence / absence inventories to include consideration of the:

- **Ecological needs of species.** For example:
  - How far does a species need to travel to eat, live and reproduce and over what time frame/s (e.g. does the species exhibit seasonal foraging patterns, undertake annual migrations, or return to natal nesting beaches to reproduce)?
  - Do individuals utilise particular routes (e.g. migratory corridors) or sites (e.g. nesting and nursery areas, spawning grounds)?
  - Which habitats and species do they interact with and/or depend upon?

- **Ecological role/s** played by an individual, group or population in one or more ecosystems (e.g. in supporting habitat formation, structure and health; maintaining a balanced food web; nutrient cycling; supporting other marine life, etc.).

- **Ecological processes** that structure ecosystems and contribute to their function and health. Some will be common across terrestrial and marine environments, such as[9]:
  - predator-prey trophic interactions in a food web;
  - complex mutualistic interactions in high diversity ecosystems;
  - inter- or intraspecific competition.

Others will be particular to the marine environment, such as[9]:
  - connectivity and dispersal of juveniles and adults (e.g. coral or fish larval dispersal in ocean currents);
  - important migration routes (e.g. for whales or whale sharks);
  - ontogenetic and physical shifts in habitat use for many tropical marine species (e.g. lobsters, reef fish, sea turtles etc.);
  - breeding and aggregation grounds of iconic or keystone species.

Spatial and temporal variation, noting that:
- Spatial variation can be considerably greater in marine systems compared with terrestrial as there are fewer barriers to the movement of organisms and those that exist (e.g. ocean currents) are not stable[23].
- Currents and wave energy are able to shift and shape habitats and ecosystems in very short spaces of times (e.g. mussel beds which may settle and dissipate within relatively short time spans).

- Environmental and temporal cues come into play in determining the location and timing of aggregations or congregatory events of species e.g. to spawn or feed. While transient, these events may play a critical role in maintaining populations of a species or broader ecosystem dynamics[9].

Capturing this spatial and temporal variation in the BES baseline is important and will need to be factored into the design of field assessments. For example:

- surveys may need to cover an extensive area, be done during a specific season, over several seasons, or be repeated over several years to ascertain a reliable baseline condition e.g. for a particular species or ecosystem service[2].
- mapping of pelagic (water column) habitats may require long-term monitoring of environmental parameters using, e.g. wave buoys to establish mean conditions.
- historic data and trends (e.g. relating to historic sea turtle nesting beach activity) may be needed to inform current and future patterns e.g. of habitat use.

- use of appropriate buffers may be needed to help capture spatial variation e.g. in the extent of foraging areas.

These wider ecological parameters are essential for building the ecological evidence base from which to assess impacts and mitigations. Users of this guidance are directed to GPG Section 3 for further guidance on understanding marine ecosystems and biodiversity.

Integrating ecosystem services

Ecosystem services are often closely linked to biodiversity (see GPG Section 3.5) yet their assessment may need different methods, data, analytical processes and expertise. For example, studies designed to understand cultural and provisioning ecosystem services will likely benefit from a multi-disciplinary team that brings together expertise and approaches from social science, ecology, marine science and, in some cases, environmental economics.

The ecosystem service component of the BES baseline should consider both supply and demand aspects and the relationship between the two (i.e. is supply sufficient to meet demand and is it expected to continue to do so in the future), whilst recognising that supply and demand can be interlinked (e.g. a decline in supply can increase or decrease demand as is the case with harvested species: some become more valued when they are rare whilst others decline in value and are substituted)[4].

The concepts of irreplaceability and vulnerability, commonly used in the assessment of biodiversity values, are also relevant for ecosystem services[7]. For example, an ecosystem service may be considered highly irreplaceable where there are few alternative options that deliver the same ecosystem service to the same beneficiaries within the seascape[7]. These concepts are also applicable when considering ecosystem service demand. For example, where there are few alternatives to replace lost services beneficiaries will be more vulnerable than those with many options[7].

Assessments can help to determine both qualitative and quantitative aspects of ecosystem service supply and demand. Typically, a combination of qualitative and quantitative information will be needed to build an understanding of BES baseline conditions:

- Qualitative assessment may include, for example:
    - descriptions of underlying ecosystem structure and function.
    - identifying priority ecosystem services.
    - building an understanding of cultural and other intangible ecosystem services.
    - identifying pathways from ecosystem service source to beneficiary.
    - why or how a particular service is used and valued.
    - rival or competing uses of ecosystem services in the seascape.
    - perceptions of how ecosystem service use has changed over time etc.
    - existence and acceptability of alternatives (in space, type and/or time).

- Quantitative measures may include, for example:
    - the level of supply of a service.
    - pathways from ecosystem service source to beneficiary.
    - use and benefit derived (monetary and/or nonmonetary).
    - changes in ecosystem service supply or demand over time.
    - current and potential future demand for ecosystem services over space and time.
    - existence of alternatives.

There are many different approaches to support the identification, prioritisation, assessment, mapping and valuation (monetary and non-monetary) of ecosystem services. Whilst most of the guidance and tools have been developed for terrestrial settings, many can be adapted and applied for assessing marine ecosystem services. A number of recent studies, reviews and online platforms profile the different tools, data and approaches for marine and coastal ecosystem service assessments[24,25,26,27,28,29,30]. Box 8 highlights some of the benefits using spatial tools to map ecosystem service flows, whilst Boxes 9 and 10 feature an adapted version of the Ecosystem Services Review[31] and its application in a marine environment; a structured methodology that helps build an understanding of ecosystem service baseline conditions.

The perceptions of what is 'useful' and therefore defined as an ecosystem service can vary over time, over space and between people, even if the ecological system itself remains in a relatively constant state[32]. Some ecosystem services, particularly cultural ecosystem services, are also unique to their location and valued in ways that are specific to individuals, communities and cultures. They cannot be recreated elsewhere or replaced with substitutes if lost. These benefits may be difficult, often impossible, to capture through quantitative assessment and spatial tools and interaction with relevant stakeholders is therefore essential. The use of open and flexible participatory approaches in ecosystem service assessment (see Box 11) is vital in building understanding of the presence of ecosystem services in the seascape and how ecosystem service benefits are utilised and valued by different people over space and time. A precautionary approach to the integration of ecosystem services, and particularly cultural values, into the baseline is needed.

Box 8: Spatial tools for assessing marine ecosystem services

The representation and assessment of marine and coastal ecosystem services has rapidly progressed over recent years. Spatial ecosystem service models offer one means for modelling ecosystem services that provide a set of tested models and equations that help to quantify different ecosystem services in an established framework. Using a GIS based approach considers a whole ecosystem, including humans and the environment, rather than managing one issue or resource in isolation. By modelling ecosystem services in a GIS, outputs can be based on monetary, quantitative or qualitative values and how they change across an ecosystem over space and time. Key benefits of using GIS-based ecosystem service tools include:

- Integration of ecological, social and economic features and goals
- Ability to identify and model stakeholder beneficiaries and their use of ecosystem services and resources
- Consideration of ecological- not just political- boundaries
- Model complexity of natural processes and social systems
- Incorporating understanding of ecosystem processes and how ecosystems respond to environmental impacts
- Ability to compare responses across different scenarios
- Visual and interactive tool for engaging multiple stakeholders in a collaborative process to define problems and find solutions

Regardless of the tool or approach adopted, there are several important factors that must be considered when identifying and applying ecosystem service tools:

- Application of the ecosystem approach is an important way forward in the application of ecosystem service tools. The right tool promotes the integration of multiple ecosystem service components with related biodiversity, social and economic components. This helps build the business case for the integrated management of resources, the identification of indicators for monitoring and facilitates engagement with a range of stakeholders related to and impacted by changes to marine ecosystem services.
- Use of robust datasets and monitoring approaches are key to producing quality and representative outputs.
- Robust approaches and tools need to be supported by transparent reporting to ensure the limitations of tools are clearly understood and to promote the replication of modelling over time. If assessments need to be repeated and compared across geographic scales, regions and temporal periods, this capability must be considered in each tool.
- Understanding the current baseline situation of ecosystem services in a marine environment is important for assessing impacts and identifying management actions. Scenario models help to define and assess possible future trends and impacts and can have as much- if not more- influence in decision making as any other output.
- In order to represent the relative importance of components and indicators of marine ecosystem services, tools and models should allow for the weighting of such components. Weighting of components and indicators must be carefully considered and supported by stakeholder engagement and scientific literature.

- It is important to select a tool that helps understand the pressures and impacts to ecosystem services, not just the quantification of ecosystem services. Understanding the drivers of change and responses to impacts allows for the full consideration of mitigation activities and identification of indicators and thresholds for monitoring.
- Calculating the uncertainty of ecosystem service assessments helps to understand the confidence of outputs and identify the supplementary information that needs to be included in decision making. An understanding on the limitations of tools also helps identify the most suitable approach for the representation of ecosystem services.

It must be recognised that outputs produced from ecosystem service tools do not provide a definitive answer; they present important information that must be assessed with other sources of information to best represent the dynamics and impacts on ecosystem services in the marine environment. The results from the application of ecosystem service tools should be assessed against other features in the ecosystem, especially biodiversity and socio-economic features.

Box 9: Ecosystem Services Review

The Ecosystem Service Review (ESR) is a structured methodology that helps projects to identify priority ecosystem services in order to more effectively manage risks and opportunities arising from their operation. The ESR is an important activity in understanding the baseline situation regarding ecosystem services in an area, including the types of ecosystem services supported in the environment, priority stakeholders who depend on ecosystem services and those services that the company depends upon. It is an effective way to identify potential social and environmental risks and mitigation activities for integration into ESIA, Ecological Management Plan, Biodiversity Action Plan, social programmes and operational activities.

The following approach to ESR has been developed by Fauna & Flora International (FFI) and has been adapted from the Corporate Ecosystem Services Review[31] approach published by the World Resources Institute (WRI), World Business Council for Sustainable Development (WBCSD), and the Meridian Institute (MI). FFI has adapted the ESR through application in different land and seascapes and for various operators. The worksheet has been amended to facilitate efficient data capture and correlation to company policies, the link between habitats, biodiversity components and the services they provide have been strengthened and different methods of visual representation have been explored to promote communication of results in reports. Through continued application in real seascapes, the ESR will continue to evolve to meet company and stakeholder needs.

The generalised stages of the ESR process are summarised in the figure below:

As a first objective, the ESR identifies the dependencies of local stakeholders on ecosystem services within a project's area of influence as well as the impacts that stakeholders might exert on these ecosystem services. In addition, the ESR identifies the company's ecosystem service dependencies and impacts related to the project activities. With this information, the ESR helps to transparently detail the current avoidance, mitigation and restoration activities in place to minimise the impacts on these ecosystem services. Gaps in these management activities are identified and indicators for monitoring and evaluation are established based upon the correlated biodiversity, environmental and social parameters connected to these ecosystem services. From this, the operation can prioritise the ecosystem services that the company depends upon and impacts, and those services that are of significance to stakeholders in the wider ecosystem.

The value of an ESR lies in the collaboration between a project's social, environmental and planning teams. The process benefits from data from social and environmental (specifically biodiversity) baselines and ideally a workshop including the project's environment, social and engineering teams. The purpose of the workshop is to review information on ecosystem services, community and project impacts and dependencies and to develop management actions and interventions. The output of the ESR is a list of priority mitigation actions which should be fed into various management documents including the ESIA and the Biodiversity Action Plan. Moreover, it highlights the link between people and the environment and facilitates the identification of management priorities of Health, Safety and Environment and Community Relations teams. This should be an iterative process – the results of which inform adaptive management actions and processes.

Box 10: Case study - Application of the Ecosystem Service Review methodology for offshore gas field development in Colombia.

The Caribbean coastline of Colombia is rich in marine biodiversity, natural resources and cultural heritage. There is a strong link between the environment and the cultural practices of the indigenous communities existing in this landscape, which is being impacted through development of towns and infrastructure on the coast, an increasing utilisation of resources, such as commercial fishing ventures, and degradation and increasing scarcity of resources such as water availability. Moreover, natural resources are being extracted at an increasing rate off the coastline.

In 2015, FFI undertook a programme of work with one developer undertaking exploratory oil drilling activities approximately 40km offshore of northern Colombia, situated in an area with several existing oil operations and exploratory licenses being developed. Having undertaken biodiversity and social baselines and an EIA for planned exploratory activities, the operator wanted to take an ecosystem approach to understanding the risks and dependencies to ecosystem services in the marine and coastal environment in addition to assessing how the mitigation hierarchy was being applied to minimise and mitigate these risks.

In Colombia, there is a legal requirement administered by the ***Ministerio de Ambiete y Desarrollo Sostenible***, República de Colombia, to identify and evaluate impacts to ES[33]. This document outlines the requirement for comprehensive baseline and impact assessments, taking into account a landscape or seascape approach that considers the biodiversity and human use aspects of the ecosystem. Whilst the operation is not subject to lender safeguard requirements, internal compliance with standards for the management of biodiversity, environmental and social risks is required and supports the company's commitment to demonstrating best practice.

FFI's adapted version of the ESR tool (as described in Box 9 above) was used to assess these links with ecosystem services and identify the risks and dependencies of the stakeholders and operation. The ESR application included a thorough desktop review of EIA reports, baseline assessments, company commitments and literature studies, a field trip to the region to understand the interaction and dependencies of communities with the marine and coastal environment and a workshop with the environmental team and environmental experts to undertake the ESR.

To this end, potential indirect and cumulative impacts were able to be identified and associated with the relevant beneficiaries in the landscape as well as the dependencies of the operation. Whilst the direct impacts to ecosystem services were considered to be low, the potential for indirect and cumulative impacts were significant and if not managed sufficiently, could lead to further degradation to ecosystem services that communities depend upon for their livelihoods and cultural identity. Indicators for representing ecosystem services were identified in the ESR, largely based upon the biodiversity and ecosystem functions that underpin them.

By undertaking the ESR at the early stage of the project development, the proponent was able to identify gaps in information collected during baseline and make recommendations for priority focus of new data collation. The ESR helps to 'data mine' and extract more information from these complimentary studies by making links between the environmental, biodiversity and social components, helping to develop a deeper and broader understanding on ecosystem services in the marine and coastal landscape. Moreover, as this ESR was completed prior to the full operational ESIA, the opportunity for more integrated management actions and monitoring indicators has been realised. Indicators for the monitoring and evaluation of ecosystem services were recommended, with the next step to be building the evidence base to support the implementation of indicators and the thresholds for managing change.

Box 11: Participatory approaches in ecosystem service assessment.

Participatory approaches are essential in the identification and prioritisation of ecosystem service dependencies, for building understanding of service demand among stakeholders – now and in the future – and for identifying potential social and cultural consequences of project impacts[34]. Participatory approaches involve processes in which stakeholders are able to express their knowledge, experience, concerns, preferences and needs. Meaningful and inclusive engagement with stakeholders is fundamental to this and stakeholder engagement should involve all relevant stakeholders and rights-holders in a transparent process to identify and prioritise ecosystem service dependencies as part of developing the BES baseline.

There are a range of different engagement tools that can be used to support the participatory assessment of ecosystem services. These tools can be categorised as either survey-based (e.g. structured/semi-structured questionnaires or interviews, focus groups) or deliberative (e.g. discussion groups) and guidance is available to support their application. For example:

- Slocum, N. (2003). Participatory Methods Toolkit. A Practitioner's Manual. UNU-CRIS, King Baudoin Foundation, Flemish Institute for Science and Technology Assessment, Brussels, pp.166.
- Community Tool Box – bringing solutions to light.
- National Ecosystem Approach Toolkit (NEAT tree): Engagement Tools
- Infield, M., Morse-Jones, S. & Anthem, H. (2015) G.R.A.C.E. Guidance for the Rapid Assessment of Cultural Ecosystem Services. Version 1.
- Fauna & Flora International: Tools for participatory approaches
- Kenter et al. (2014). Shared, plural and cultural values: a handbook for decision makers. UK National Ecosystem Assessment Follow-on Phase. Cambridge; UNEP–WCMC.

Ecosystem services can also be assessed indirectly, using proxy biodiversity and environmental features and values to represent ecosystem services (e.g. where a species or habitat is directly related to the delivery of ecosystem services, such as a provisioning or cultural service). Where proxy features are used, it is important that the links between these features and the ecosystem services they represent are understood and clearly documented along with any underlying assumptions or limitations.

Step 5 - Baseline reporting

Once data have been collated, analysed and interpreted the baseline report is compiled in which BES are characterised across the identified study area. The baseline must include sufficient biodiversity and biophysical data to enable ecological characteristics to be undertaken to a level where there may be determination of the ecological function, patterns and processes. The baseline report should contain the full dataset and information gathered through desktop analysis and field sampling, including all tabular results, photographs (with descriptions) spatial datasets (with appropriate metadata) and related GIS project/s.

The marine oil and gas sector has an important role to play in improving regional knowledge on the BES of the marine realm. Wherever possible, raw data, maps and technical reports relating to BES should be made accessible through publicly available repositories.

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Appendix 5 – Conservation sector guidance documents, tools and resources to support good practice design and implementation of marine conservation projects

To support the development and implementation of marine conservation projects, the conservation sector has produced various documents, tools and resources. Most are freely available online and are intended to promote good practice marine conservation by practitioners (e.g. marine protected area (MPA) managers, coastal resource managers). They provide an evidence-based approach, underpinned by sound science and practical experience, to help users design and deliver effective projects. As such, these resources can be used to support the design of good practice marine biodiversity offsets.

The list below includes a selection of guidance documents and resources to support the design, development and implementation of marine conservation projects. Resources are categorised under the following themes:

- Ecosystem approaches and marine spatial planning
- Socio-economic and governance considerations around marine conservation and marine resource management
- Design, establishment and management of marine protected areas
- Climate adaptation planning
- Marine ecosystem restoration
- Habitat-specific resources for marine conservation

The selection of resources included here is not intended to be a comprehensive list and a wide range of other relevant materials are available.

It is important to recognise that there is no single approach to developing and implementing marine conservation projects and the most appropriate and effective approach will vary in different contexts and cases. It will always be important to consider and consult available international and relevant regional, national and/or local guidance and expertise early in the project design process.

Ecosystem approaches and marine spatial planning

The ecosystem approach, defined by the Convention on Biological Diversity, is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

Marine spatial planning is a framework which provides a means for improving decision-making as it relates to the use of marine resources and space. It is based on principles of the ecosystem approach and ecosystem-based management. All marine spatial planning exercises are spatial and temporal, utilising forecasting methods and fully taking into account seasonal dimensions.

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) Marine Spatial Planning - A Step-by-Step Approach toward Ecosystem-based Management resource provides a comprehensive overview of marine spatial planning, including the establishment of appropriate authority for the planning and implementation of marine spatial planning, organisation of stakeholder participation, implementation and enforcement of the spatial management plan, and monitoring and evaluating performance of the plan. It is especially targeted to situations in which time, finances, information and other resources are limited, and it focuses on describing a logical sequence of steps that are all required to achieve desired goals and objectives for marine areas.

The Centre for Ocean Solutions has published the Decision Guide: Selecting Decision Support Tools for Marine Spatial Planning to assist practitioners in selecting appropriate decision support tools, models and methods that can help them conduct marine spatial planning in their own jurisdictions. The guide also provides case studies illustrating how different decision support tools are commonly used to address marine planning related needs, and provides a simple priority needs assessment to help tool developers and practitioners determine where future efforts and collaborations could best be allocated. Guiding Ecological Principles for Marine Spatial Planning, also published by the Centre for Ocean Solutions, is also a useful reference to developing an understanding of the ecological principles for marine spatial planning, which should be incorporated into a decision-making framework.

Options for Delivering Ecosystem-Based Marine Management (ODEMM) focuses on the structure, tools and resources required to choose and evaluate ecosystem-based management options . A range of tools are available to carry out assessments and aid decision making, such as a pressure assessment, ecological risk assessment and cost and benefit analyses. The resources and knowledge provided have been tested in European regional seas, but the ideas and tools are suitable for any marine environment.

The Good Coastal Management Practices in the Pacific: Experiences from the Field report presents 17 case studies of coastal management initiatives from a wide a range of countries and territories throughout the Pacific region. Case studies illustrate examples of local, provincial, national and regional scales of actions.

Socio-economic and governance considerations around marine conservation and marine resource management

In the development and implementation of marine conservation projects it is crucial for indigenous peoples and other communities living in and around the project area who both depend on and impact marine resources and ecosystem services to be respected and, as stakeholders, to be meaningfully engaged in project decision-making. The resources listed below provide information and guidance on sustainable livelihoods, community-based management of marine conservation projects, impacts of conservation interventions on human wellbeing, integrating rights and social issues in conservation, participatory approaches, cultural ecosystem services, FPIC (Free, Prior & Informed Consent), and socioeconomic assessments.

The Sustainable Livelihoods Enhancement and Diversification (SLED): A Manual for Practitioners builds on the lessons of past livelihoods research projects as well as worldwide experience in livelihood improvement and participatory development practice. The manual provides development practitioners with an introduction to the SLED process and provides guidance for practitioners facilitating that process.

The Locally Managed Marine Area (LMMA) Network is a group of practitioners involved in various community-based marine conservation projects, primarily in the Indo-Pacific, who have joined together to learn how to improve their management efforts. They are interested in learning under what conditions using an LMMA strategy works, doesn't work, and why. The Network provides information and resources on LMMAs and community-based adaptive management, and training in aspects including project design, monitoring, data management and analysis, fundraising, and communications.

Evaluating the Impacts of Conservation Interventions on Human Wellbeing - Guidance for Practitioners presents the steps in social impact evaluation and key issues to consider; an understanding of how decisions that evaluators make depend on the questions the evaluation aims to answer, the characteristics of the intervention, and the organisational context; direction to appropriate methods and tools; and case studies drawn from real life examples to illustrate a range of situations that practitioners could find themselves in, and potential approaches to take under different circumstances.

The INTRINSIC: Integrating Rights and Social Issues in Conservation (A Trainer's Guide) manual has been designed to build capacity and improve conservation policy and practice by increasing environmental and social sustainability of conservation projects and enabling positive, equitable outcomes for both nature and people. It provides a flexible package of training materials with modules on the following: community and social diversity; gender and conservation; introduction to governance; rights-based approaches to conservation; equity, participation and power; conflict management; and livelihoods and wellbeing. The manual consists of presentations, interactive activities, and exercises involving case studies, role play, group discussions and feedback.

FPIC and the Extractive Industries is a guide to applying the spirit of free, prior and informed consent in industrial projects that explores what it terms the 'spirit of FPIC', the key elements of which are deliberation and considering all options equally and fairly. It focusses on understanding the essence of what it means to respect individual and collective rights, and for people to have a meaningful voice in deliberative decision-making processes about their own development.

Fauna & Flora International have developed a Livelihoods & Governance Library, containing a number of resources related to the socio-economic and governance aspects of conservation projects. The tools and concepts presented here are applicable across both terrestrial and marine systems, and are contained under themes including tools for participatory approaches, assessing cultural ecosystem services, and integrating conservation, livelihoods and governance.

Socioeconomic Manual for Coral Reef Management is intended to help reef managers understand the steps in a socioeconomic assessment, and provide practical guidelines on how to conduct baseline socioeconomic assessments of coral reef stakeholders. The social, cultural and economic issues are discussed as well as the organisation and resource governance of coral reef management. The socioeconomic information collected and the processes suggested here will help reef managers in management, development, research, monitoring and policy at a site. The baseline information may also contribute to national, regional and international comparisons of data, which are useful for science and policy-making.

Design, establishment and management of marine protected areas (MPAs)

Marine protected areas (MPAs) involve the protective management of natural areas so as to keep them in their natural state. MPAs can be conserved for a number of reasons including economic resources, biodiversity conservation, and species protection. They are created by delineating zones with permitted and non-permitted uses within that zone.

The International Union for Conservation of Nature (IUCN) have produced two regional toolkits for MPA managers and practitioners, offering guidance for the day-to-day running of MPAs. Managing Marine Protected Areas: A Toolkit for the Western Indian Ocean (WIO) is designed to support MPA managers in the WIO by providing a hands-on guide to topics ranging from communications, monitoring coral reefs, energy sources, solid waste disposal, to octopus and sea cucumber fisheries. The toolkit is designed to address management issues relevant to all types of MPAs, from community based, locally managed areas to nationally gazetted marine parks. Managing Marine and Coastal Protected Areas (MCPA): A Toolkit for South Asia assists MCPA managers and practitioners in South Asia to assess current and consolidated information and guidance relating to all stages of MCPA establishment and management issues faced in day-to-day operations

'How is your MPA doing?' is a guidebook developed by the IUCN Programme on Protected Areas that offers managers and other conservation practitioners a process and methods to evaluate the management effectiveness of MPAs for the purposes of adaptive management. The evaluation is based on natural and social indicators that measure the effectiveness of management actions in attaining goals and objectives that are specific to MPAs, the marine environment and coastal communities. It presents a flexible approach that can be used in many types of MPAs, such as multiple-use areas or no-take zones, where each may have different goals and objectives.

Designing Marine Protected Area Networks to Achieve Fisheries, Biodiversity, and Climate Change Objectives in Tropical Ecosystems provides an integrated set of 15 biophysical principles that field practitioners can use to design MPA networks to achieve fisheries, biodiversity and climate change objectives simultaneously. These principles are designed to be used in combination with important social, economic and political considerations in marine spatial planning.

Establishing Resilient Marine Protected Area Networks - Making it Happen provides information to better understand the role of MPA networks for achieving marine conservation. It utilises scientific knowledge, institutional experience and global case studies to present the most relevant lessons in building resilient and functional networks.

Global Ocean Protection, Present Status and Future Possibilities provides evidence-based recommendations on improving and accelerating actions on delivering ocean protection and management through marine protected areas and facilitates the sharing of experiences and lessons learned.

The IUCN Green List Standard is a global standard for protected areas in the 21st Century. The overarching objective of the Standard's implementation programme is to increase the number of protected and conserved areas that are effectively and equitably managed and deliver conservation outcomes. The IUCN Green List Standard is organised into four components of successful nature conservation in protected and conserved areas: the baseline components concern Good Governance, Sound Design and Planning, and Effective Management; and together these support the component on Successful Conservation Outcomes. Each component has a set of criteria and each criterion has a set of indicators to measure achievement. These indicators may be adapted in the context of each participating jurisdiction, to allow for reflection of regional and local characteristics and circumstances in which protected and conserved areas operate. Guidance for this process is detailed in the accompanying IUCN Green List User Manual.

Climate adaptation planning

Climate change adaptation planning is a process designed to help identify sensitivities and vulnerabilities to changing conditions and devise strategies to help ecosystems and people cope with changes. It focuses on building resilience (i.e. the ability of a system to absorb shocks, disturbances and long-term changes and continue functioning) to changing conditions such as climate variability and extremes.

Building Resilience to Climate Change: Ecosystem-based adaptation and lessons from the field highlights some practical adaptation planning processes for the development of Ecosystem-based Adaptation (EbA) and conservation adaptation strategies. Case studies cover a range of adaptation interventions, focussed on both adaptation for conservation purposes, and supporting people to adapt to climate change through EbA. Many of the case studies have both elements, in recognition of the fact that in order to continue to provide services to enable people to adapt to climate change, ecosystems themselves will also need to adapt. The document summarises some current applications of the EbA concept and its tools used around the world, and also draws lessons from experiences in conservation adaptation. EbA in a Marine Protected Area is presented as a case study.

The CBD Synthesis Report on Experiences with Ecosystem-Based Approaches to Climate Change Adaptation and Disaster Risk Reduction presents key findings from a 2016 CBD technical workshop on EbA and and Ecosystem-based approaches to disaster risk reduction (Eco-DRR). The workshop was attended by experts and practitioners from a wide range of countries and organisations who shared and discussed experiences of national and regional efforts to implement EbA and Eco-DRR measures. The report looks at what linkages exist between EbA and Eco-DRR, the policy and institutional context for EbA and Eco-DRR, trade-offs, thresholds and limitations, implementation of EbA and Eco-DRR, monitoring and evaluation, the contribution of indigenous peoples and local communities to EbA and Eco-DRR, and gender mainstreaming. Case studies on the protection and rehabilitation of degraded mangrove forests, and on assessing vulnerability and adaptation of mangroves and associated ecosystems are presented.

Tools for Coastal Climate Adaptation Planning - A Guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning is targeted at practitioners and decision makers involved in coastal zone management, natural resource management, protected area and habitat management, watershed management, conservation and local planning. It focusses on spatially explicit solutions for climate-related planning, and helps users to select appropriate tools for their projects. While the guide is targeted at users in the coastal United States, the information and tools should also be applicable to coastal and inland locations internationally.

Options for Ecosystem-based Adaptation in Coastal Environments: A Guide for Environmental Managers and Planners is a strategic resource for those involved in planning and implementation of coastal Ecosystem Based Adaptation (EBA). It aims to provide a broad understanding of the principles and concepts of coastal EBA, present a range of different coastal EBA options, illustrated with existing examples, and discuss the issues and challenges that need addressing in EBA implementation.

Climate Change Adaptation Planning - A Toolkit for Biodiversity Conservation Project Sites guides the development of climate adaptation plans for biodiversity and people at project sites, with an aim to increase resilience to climate change. The toolkit is aimed at biodiversity conservation project teams who wish to develop climate change adaptation plans for their project site and it takes a 'bottom-up' approach, involving project teams, partners and local communities who live and work at the sites day to day. It is designed to support teams through a process of identifying climate adaptation strategies to incorporate into an existing site project plan *or* to support the development of a project plan for a site project that incorporates climate adaptation strategies from the outset. It can be used at any stage in a project's lifecycle, but is best done at the time of the project development or review. The toolkit includes suggested outlines for a series of workshops and consultations, and a template for a site-based Climate Adaptation Plan, outlining the short- and longer-term actions needed to increase resilience and adaptive capacity. Although focussed on agricultural landscapes, many of the resources presented here can be adapted and applied to the marine context.

The IUCN Resilience Science Group has produced a series of Working Papers aimed at promoting resilience to climate change in different marine habitats. Coral Reef Resilience and Resistance to Bleaching highlights a variety of resistance and resilience factors and provides an overview of some of the tools and strategies we can use to enhance coral reef resilience. Managing Mangroves for Resilience to Climate Change provides some considerations for conservation practitioners as they design conservation strategies for mangroves. It describes the impacts of climate change on mangroves and outlines tools and strategies that enhance mangrove resilience. Managing Seagrasses for Resilience to Climate Change presents an overview of the impacts of climate change and other threats to seagrass habitats, as well as tools and strategies for managers to improve seagrass resilience.

Care International's Community-Based Adaptation Toolkit provides information, tools and guidance to facilitate the design, implementation and management of Community-Based Adaptation (CBA) projects. The toolkit offers a practical 'how-to' guide for project teams completing the project cycle for CBA projects. It includes step-by-step guidance and recommended tools for all stages of the project cycle, and CBA Project Standards to help ensure high quality analysis, design, implementation and information & knowledge management in CBA projects. Though not a biodiversity-focussed toolkit, there are important

Marine ecosystem restoration

Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. In the context of the mitigation hierarchy, it is the measures taken to improve degraded or removed ecosystems following exposure to impacts that cannot be completely avoided and/or minimised, in order to return an area to the original ecosystem that occurred before impacts.

Reef Restoration Concepts & Guidelines: Making Sensible Management Choices in the Face of Uncertainty contains simple advice on coral reef restoration for coastal managers, decision makers, technical advisers and others who may be involved in community-based reef restoration efforts. Despite much uncertainty in the science underpinning restoration, not least due to the great complexity of reef ecosystems, there are many useful lessons in what works and what doesn't from previous work that can valuably inform future restoration efforts.

The Society for Ecological Restoration International has produced Guidelines for Developing and Managing Ecological Restoration Projects. This document outlines technical application of ecological restoration treatments across all geographic and ecological areas – whether terrestrial, freshwater, coastal or marine – to improve biodiversity conservation outcomes for all ecosystems, secure the delivery of ecosystem services, ensure projects are integrated with socio-cultural needs and realities, and contribute to the 2030 Agenda for Sustainable Development.

Transplanting *Posidonia* Seagrass in Temperate Western Australian Waters: A Practical 'How To' Guide provides practical advice for transplanting sprigs of ***Posidonia*** species in Western Australia, and covers logistical considerations, equipment required, donor material selection, recipient site selection, manual transplanting procedures and monitoring success. It is believed that these techniques, or some modification of these, could be effective for similar species of seagrass species growing in similar environments around the world.

Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters is another useful seagrass restoration resource, that discusses issues that should be addressed in planning seagrass restoration projects, describes different planting methodologies, proposes monitoring criteria and means for evaluating success, and discusses issues faced by resource managers.

The Reef Rehabilitation Manual captures the learnings of worldwide research into reef rehabilitation and seeks to reduce the proportion of reef rehabilitation projects that fail. It provides detailed hands-on advice, based on lessons-learnt from previous experience, on how to carry out coral reef rehabilitation in a responsible and cost-effective manner. Additional information and case studies to support this manual can be found here.

Ecological restoration in the deep sea: Desiderata (Scientific paper) offers guidance on planning and implementing ecological restoration projects for deep-sea ecosystems that are already, or are at threat of becoming, degraded, damaged or destroyed. It presents two deep-sea restoration case studies, in which a set of socio-economic, ecological, and technological decision parameters that might favour (or not) their restoration are examined. Costs for hypothetical restoration scenarios in the deep sea are also estimated.

The Community-Based Mangrove Rehabilitation Training Manual is aimed at all those that are involved in mangrove rehabilitation, and provides science-guided protocols in mangrove rehabilitation, focussing on biophysical and socioeconomic considerations, nursery considerations, and outplanting procedures and protocols. The manual also contains a Guide on Mangrove Damage and Recovery Assessment; a tool that can be used to determine the effects of natural calamities in mangrove and beach forest ecosystems, which in turn provides a strong basis for developing area- and needs-specific plans for coastal forest and community rehabilitation.

The Mangrove Action Project has produced various resources on mangrove rehabilitation, including: 1) Ecological Mangrove Rehabilitation: A Field Manual for Practitioners, which presents a detailed process of mangrove rehabilitation and case studies from around the world that are representative of both successful and failed attempts at mangrove restoration; and 2) Five Steps to Successful Ecological Restoration of Mangroves, which provides a summary description of several preferred methods for planning and implementing mangrove rehabilitation.

Habitat-specific resources

The following resources provide habitat-specific information and guidance for application in the development and implementation of marine conservation projects. Resources cover coral reef (predominantly), mangrove, seagrass and deep-sea habitats, and seamount features, though it should be noted that a wide range of habitat-specific information and guidance has been developed for application in particular seascapes, and conservation practitioners are advised to consult with relevant experts for further guidance and recommended resources.

Coastal Conservation and Management - An Ecological Perspective (E-book or hardcopy available for purchase) provides a synthesis of the range and variation of the main coastal formations and includes practical guidance on their management. The book discusses all the main coastal habitats of importance for nature conservation (saltmarsh, shingle, sand dune and seacliff), and combinations of these habitats (estuaries and other coastal wetlands). It provides an overview of the importance and range of variation of each habitat and coastal ecosystem, with some key management options for each identified.

Preserving Reef Connectivity: A Handbook for Marine Protected Area Managers aims to help managers of coastal areas, in particular those of coastal MPAs, understand and apply the concept of connectivity in their work. Connectivity issues relate to the movement in marine environments of water – and with it sediments, nutrients and pollutants – and of marine organisms.

Directory of Remote Sensing Applications for Coral Reef Management aims to help reef managers make better use of remotely-sensed data. It details opportunities provided by remote sensing, the limitations of different methods, and considerations for implementation.

Catchment Management and Coral Reef Conservation is a practical guide for coastal resource managers to reduce damage from catchment areas based on best practice case studies. The book aims to assist coastal resource managers deal with the problems arriving at the coast from rivers and streams, including problems around sediment, nutrient, pesticide and litter pollution damaging reefs.

No Reef Is an Island: Integrating Coral Reef Connectivity Data into the Design of Regional-Scale Marine Protected Area Networks. This paper integrates coral reef connectivity data into a conservation decision-making framework for designing a regional scale MPA network that provides insight into ecological and political contexts.

Methods for Ecological Monitoring of Coral Reefs aims to help managers of coral reefs select appropriate ecological monitoring programs, protocols and methods for their coral reef management needs, including information on: how monitoring can help management; how to choose the best methods to suit your needs; and the pros and cons and associated costs of a wide range of monitoring methods. The protocols and methods outlined in this book represent the ones most commonly used on coral reefs around the world.

Healthy Reefs for Healthy People - A Guide to Indicators of Reef Health and Social Well-being in the Mesoamerican Reef Region provides a toolkit for field scientists, managers and other stakeholders engaged in long-term study and conservation in the Mesoamerican Reef (MAR) ecoregion. It provides indicators of environmental and social health tailored to the MAR, and 'red-flag' thresholds to help recognise when these indicators are signalling 'time-to-take-action' conditions. It provides practical suggestions for how reef stewards can apply these indicators to real-life situations, to ultimately turn these indicators into action to ensure the long-term ecological integrity and sustainability of Mesoamerican reefs.

Reefs at Risk Revisited provides a detailed assessment of the status of and threats to the world's coral reefs. The information is intended to raise awareness about the location and severity of threats to coral reefs. These results can also catalyse opportunities for changes in policy and practice that could safeguard coral reefs and the benefits they provide to people for future generations. The outputs of *Reefs at Risk Revisited* (report, maps, and spatial data sets) can be used by marine conservation practitioners, resource managers, policy makers and development agencies to identify opportunities to protect reefs, set priorities and plan interventions.

Coral Disease Handbook - Guidelines for Assessment, Monitoring & Management outlines procedures for describing signs, measuring disease impacts, monitoring disease outbreaks, assessing causes, and managing reefs to minimise losses due to disease.

The Reef Resilience website provides useful guidance on the design of marine protected areas with consideration for the maintenance of ecological connectivity among and between habitats.

Mangroves for Coastal defence: Guidelines for Coastal Managers and Policy Makers provides practical management recommendations to coastal zone managers and policymakers. It helps the reader to assess the risk context in a target area, to define hazard-specific mangrove management interventions and to incorporate these in risk reduction strategies, climate change adaptation protocols and broader coastal development planning. Case studies provide practical examples of mangrove management approaches.

European Seagrasses: An Introduction to Monitoring and Management provides a basic introduction to monitoring and management of European seagrasses, though the practices provided here could be applied globally. Basic monitoring strategies and parameters are described, as well as recommendations as to how seagrass beds can be protected and recovered through environmental management.

Ecological restoration in the deep sea: Desiderata (Scientific paper, referenced above in 'Marine ecosystem restoration') offers guidance on planning and implementing ecological restoration projects for deep-sea ecosystems that are already, or are at threat of becoming, degraded, damaged or destroyed.

Seamounts: Ecology, Fisheries & Conservation (E-book or hardcopy available for purchase) reviews all aspects of seamount geology, ecology, biology, exploitation, conservation and management. It is written by leading seamount experts and is aimed at fisheries scientists and managers, fish biologists, marine biologists and ecologists, environmental scientists, conservation biologists and oceanographers.