GOVERNING COASTAL RESOURCES

IMPLICATIONS FOR A SUSTAINABLE BLUE ECONOMY

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FOREWORD

Our shared ocean is at risk.

Two thirds of our planet is covered by the ocean, a system that not only supports life on Earth and human well-being but also regulates the climate. The ocean provides oxygen, food, energy, water and raw materials. It offers remarkable cultural services and is a source of jobs and economic activity across our planet.

Despite its importance, the future of our world's ocean is at a critical point. Over-exploitation, pollution and climate change are causing a serious loss of marine biodiversity. Without a healthy ocean all the services it provides will be disrupted and the consequences will be dire.

The 2030 Agenda dedicates Sustainable Development Goal 14: Life Below Water to "conserve and sustainably use the oceans, seas and marine resources". As we enter the decade for achieving the 2030 Agenda, we need urgent action to mitigate the detrimental effects human activities are triggering, from those undertaken at sea or in coastal areas, to those occurring inland, hundreds of kilometres away from the coast.

A wide range of initiatives across the planet are working in this direction. This includes UNEP's ecosystem-based marine and coastal management and ocean governance work: the Sustainable Blue Economy Initiative, the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, and efforts of the Regional Seas programmes. In addition, scientific findings continue to strengthen our knowledge-base for ocean policy-making and management solutions, a focus of the UN Decade of Ocean Science for Sustainable Development (2021-2030), and the UN Decade for Action on Ecosystem Restoration (2021-2030) which UNEP is proud to co-lead with numerous partners.

This International Resource Panel report, "Governing coastal resources: implications for a sustainable blue economy", outlines key pathways through which land-based activities influence coastal resources, across land-sea boundaries and at multiple spatial scales. This report also stresses the need for a holistic governance approach that accounts for the connections between land-based activities and coastal resources. The report provides practical options to strengthen existing land-sea governance practices and presents new governance structures to reduce the impact of land-based activities on coastal resources and support the transition to a sustainable blue economy. We have a significant opportunity and responsibility to mitigate human impacts.

It is time to act and save our Blue Planet for humanity to thrive. I believe this important report of the International Resource Panel will make valuable contributions to an urgently needed shift towards more comprehensive and effective ocean stewardship, placing us on a sustainable ocean trajectory that we are all relying on. Business as usual is no longer an option. COVID-19 has demonstrated that humanity can respond collectively to a shared global challenge – let's build on this to create an unstoppable movement for sustainable oceans for All.

Ligia Noronha
Director, Economy Division
UN Environment Programme
(April 2021)

PREFACE

Historically the management of our ocean has been fragmented by natural, legal and administrative boundaries. Land-based and ocean-based activities have been governed independently creating a disconnect between where impacts are experienced and where they originate.

It is widely recognised that land-based human activities significantly impact the marine environment. For instance, estimates suggest that 80 per cent of marine pollution originates on land. Still, there are very few, if any, truly effective governance mechanisms that take account of land-ocean interactions.

Since 2007 the International Resource Panel has provided independent, authoritative and policy-relevant scientific assessments on the status, trends and future state of natural resources. In this report, our focus is on coastal resources, specifically how land-based human activities affect the quality and availability of coastal and marine resources.

This report identifies the numerous pathways through which land-based activities generate impacts on coastal resources, acknowledging that they can differ, depending on the location, type, condition and resilience of the local ecosystems. It also identifies implications for the sustainable blue economy of changes to the coastal resource base caused by land-based activities. This is further explored in detailed assessments of shrimp aquaculture and coastal mining.

Based on its scientific findings, the report calls for vastly improved governance approaches to reduce the negative impacts of land-based activities on coastal resources as well as supporting the transition to a sustainable blue economy. We have a significant opportunity and responsibility to reverse human impacts on our shared ocean.

We thank the lead authors and their team for their dedicated efforts to draw together an evidence base that demonstrates beyond question the need for enhanced governance coordination between terrestrial activities and marine resources. As the report advocates, future governance systems should not be constrained by existing boundaries which often disconnect causes from effects. Instead greater emphasis should be placed on safeguarding our natural resources, advancing the sustainable development goals of the Agenda 2030 and breaking away from current unsustainable resource use patterns.

Izabella Teixeira
Co-Chair
International Resource Panel

Janez Potočnik
Co-Chair
International Resource Panel

EXECUTIVE SUMMARY

Coastal resources - including fish, minerals and energy - are critical to people, nature and the economy, and are a focus for the emerging sustainable blue economy agenda. Whilst there is no globally agreed definition of a Sustainable Blue Economy, the working definition in this report is *an ocean-based economy that provides equitably distributed social and economic benefits for current and future generations, while restoring and protecting the intrinsic value and functionality of coastal and marine ecosystems and is based on clean technologies and circular material flows* (adapted from WWF, 2018). It has long been recognized that a particular challenge in coastal areas is the management of land-based activities that generate detrimental impacts on coastal resources in the marine environment. Many of these pressures are negative externalities of land-based human activities that are not taken into account within existing resource-governance frameworks. While a range of market-based, non-market and other interventions are worthy of consideration, the development of improved approaches to land-sea governance that take account of how land-based activities affect the quality and availability of coastal resources is the focus of this report.

The primary purpose of the study was to determine appropriate governance approaches to reduce the effects of land-based activities on coastal resources and to support the transition to a sustainable blue economy. A secondary purpose of the study was to test a new method to identify the pathways through which land-based activities affect coastal resources. This global study used a Drivers, Pressures, State, Impact, Response (DPSIR) framework, which provides a structured approach to the study of complex systems. The approach was used to assess how global scale drivers are pushing the development of land-based activities (pressures), which in turn affect the quality and availability (state) of coastal resources. The impact of changing coastal resources on a selection of sustainable blue economy sectors was then considered. Finally, the study presents an analysis of possible governance responses that can better account for, and ideally reduce, the effects of land-based activities on coastal resources and thereby support the transition to a sustainable blue economy. We used a novel iterative evidence-based analysis designed to identify the individual and cumulative effects generated by land-based activities on coastal resources. In total, over 1,000 separate pieces of evidence were reviewed, supported by three workshops to validate and refine the analysis.

We found that land-based activities generate multiple impacts of different strength on coastal resources and that biotic coastal resources are more impacted by land-based activities than abiotic coastal resources (however, this could in part be due to fewer studies focusing on abiotic resources). There is comparatively strong evidence that all biotic coastal resources are highly impacted by land-based activities, with agriculture, ports/harbours and aquaculture being particularly impactful land-based activities. Biodiversity was the coastal resource most impacted by land-based activities. By examining the dependency of sustainable blue economy sectors on coastal resources, we found that aquaculture, fishing and tourism were most vulnerable to changes in the coastal resource base arising from land-based activities. In comparison, sectors dependent on abiotic coastal resources, such as aggregate extraction, were somewhat isolated from the effects of land-based activities.

The results clearly showed that coastal resources, particularly living resources, are negatively affected by stressors generated by land-based activities that may take place at great distances from the coast. Land-based activities, however, are currently managed through sector-specific arrangements with limited, if any, regard for their effects on coastal resources. An additional barrier is that terrestrial and marine areas typically operate within separate governance frameworks with no means of coordination. Therefore, in order to ensure the effective conservation and sustainable use of coastal resources, it is necessary to develop governance approaches that holistically take account of the individual and cumulative effects of land-based activities wherever and in whatever sector they originate. In order to be meaningful, the governance approach must overcome the legal and administrative barriers that result in marine and terrestrial environments being treated as separate governance units.

Following a review of existing coastal governance approaches that support land-sea coordination, and a detailed evaluation of the governance arrangements in the extractive and aquaculture sectors, options were generated for minimizing the effects of land-based activities on coastal resources through improved governance approaches

that also support the transition to a sustainable blue economy (summarized in Figure 1). The options are aligned to International Resource Panel principles of resource efficiency and decoupling. The first group of options are intended to strengthen existing practices in land-sea governance. These are as follows:

- Ecosystem-based management should be a guiding principle of coastal resource governance, as it provides a holistic approach to the consideration of all influences on coastal resources (with an emphasis on a healthy underpinning ecosystem).
- Existing area-based management tools, with enhancement and adaptation, should be used to counteract the impacts of land-based activities on coastal resources (such as marine protected areas, marine spatial planning, integrated land-use planning and integrated coastal management)
- Improved coordinating mechanisms are needed to overcome fragmented governance between sectors and between terrestrial and marine governance arrangements.
- Implementation-focused capacity development programmes should be formulated and disseminated to target land-sea governance practitioners.
- Filling evidence gaps, particularly related to the impacts of land-based activities on abiotic coastal resources, should be prioritized and their implications for effective governance determined.

Further options arising from this study provide new insights into land-sea resource governance approaches framed around resource efficiency and decoupling. These are:

- Coastal governance should focus on the pathways connecting multiple land-based activities to coastal resources, and should not be constrained by arbitrary boundaries such as legal or administrative ones that disconnect causes from effects and frustrate coordinated governance responses.
- Regional regulatory frameworks that place a legal obligation on land-based activities to take account of coastal resource impacts should be developed to reduce the impacts of land-based activities on coastal resources.
- Natural capital safeguarding on land and at sea is a unifying principle that could be used as a common cause to connect otherwise fragmented governance systems.
- Coastal natural capital needs to be mapped and protected, as there is currently a substantial evidence gap.
- A stakeholder community must be constructed to reflect the pathways connecting land-based activities to coastal resources, rather than the typical area-based stakeholder partnerships currently in place.
- Monitoring and evaluation should focus on Impact pathways, and not merely on the condition of coastal resources.
- A decision-support tool is required to support land-sea governance focused on impact pathways that take account of different geographical contexts.

Finally, the new methodology developed and applied in this study to better understand and communicate the relationships between land-based activities and coastal resources has proved to be useful at the generic global scale and within the aquaculture and extractive sectors. The approach enabled individual and cumulative effects to be identified, along with a strong evidence base underpinning each assessment. This is an important new synthesis of such critical information. A key challenge was the sheer time required to determine the scale and direction of each relationship between an activity, the stressors it generates and the effects of those stressors on multiple coastal resources. It must also be recognized that this approach can lead to oversimplifications of what are often complex, spatially distinctive and dynamic relationships. The introduction of regional or national specificity may therefore be necessary in future assessments. The approach also enabled evidence gaps to be determined. In this study, the main gaps identified related to new activities or emerging impacts and abiotic coastal resources. However, once completed and verified, the relationships are unlikely to change substantively and could be embedded within a database or online tool to streamline future analyses.

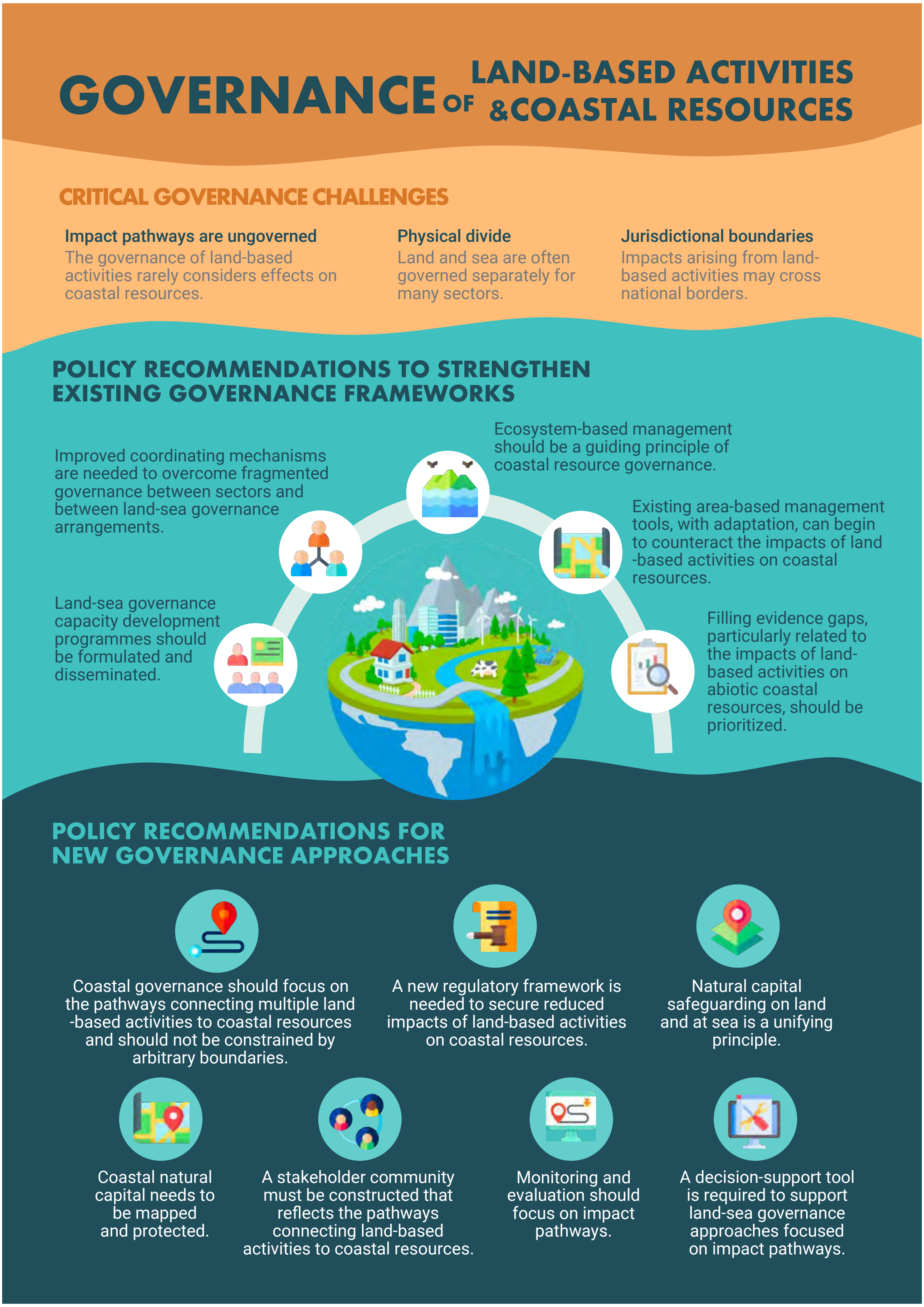

Figure 1. Summary of coastal governance recommendations

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Technical annexes supporting the analysis undertaken in this study are available online only here: www.resourcepanel.org/reports/governing-coastal-resources.

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CBD	Convention on Biological Diversity
DDT	Dichlorodiphenyltrichloroethane
DPSIR	Drivers, Pressures, State, Impact, Response Framework
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GES	Good Environmental Status
EU	European Union
HELCOM	The Baltic Marine Environment Protection Commission
ICES	International Council for the Exploration of the Sea
ICMM	International Council of Mining and Metals
IEA	International Energy Agency
IPCC	The Intergovernmental Panel on Climate Change
IRP	International Resource Panel
MIN	Minerals Policy Guidance
MSP	Marine Spatial Planning
NMVOC	Non-Methane Volatile Organic Compounds
OECD	Organisation for Economic Co-operation and Development
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAHs	Polyhydroxyalkanoic Acid
PCDDs	Polychlorinated dibenzo-p-dioxins
PCDFs	Polychlorinated dibenzofurans
SDGs	Sustainable Development Goals
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNEP-WCMC	UN Environment Programme - World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change

GLOSSARY

Abiotic coastal resources: Refers to the physical, non-living coastal materials that could be utilized by the extractive industry.

Aquaculture: Describes the farming of aquatic organisms and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production. Farming also implies individual or corporate ownership of the stock being cultivated. Aquaculture occurs in both inland (freshwater) and coastal (brackish water, seawater) areas.

Biotic coastal resources: Refers to the biological or living coastal materials that could be utilized by the extractive industry.

Coastal: While there is no formal definition of the area encompassed by the term 'coastal', in this study we used the area defined by a nation's Territorial Sea and internal Waters area as a guide. The Territorial sea is the area between a national baseline and 12 nautical miles out to sea, which confers the highest level of resource access under the UN Convention on the Law of the Sea. Internal Waters are the areas landward of a baseline and typically include estuaries, bays and river mouths. The Territorial Sea and Internal Waters, for most countries, typically contain the greatest concentration of resources and most of the economic activity within a nation's maritime area. However, some flexibility was used to reflect the reality of marine ecological connections.

Coastal resources: Denotes the coastal raw materials that could: provide food, energy and minerals; support cultural, recreation, leisure and health opportunities; and provide space for critical transport and trade infrastructure.

Decoupling: Refers to removing the link between two variables. It refers to resource decoupling (the delinking of economic growth and resource use) and impact decoupling (the delinking of economic growth and negative environmental impacts). The term double decoupling refers to delinking economic growth from resource use and from environmental impacts. Moreover, decoupling can be relative (the rate of resource use increase is lower than the rate of economic growth) or absolute (resource use declines while the economy grows).

DPSIR (Drivers – Pressure – State – Impact – Response) framework: The DPSIR framework aims to provide a step-wise description of the casual chain between economic activity (the driver), the pressures (land use change, emissions of pollutants), changes in the state of the environment (land use change, eutrophication) and impacts (such as the loss of nature or biodiversity and diminished human health, welfare or well-being), which leads to a societal response that then changes the driving forces in order to reduce the impacts.

Efficiency: Refers to a broad concept that compares the inputs to a system with its outputs. Denotes achieving more with less. The system can refer to a production process (producing more with less) or an entire economy (achieving more usefulness with total input). Efficiency includes activities to improve productivity (value added / input) and minimize intensity (input / value added).

Governance: The frameworks, processes, actors and ideas through which decisions and strategies are chosen and implemented (Oakerson, 1992; Kooiman *et al.*, 2008).

Impact: Refers to the negative environmental impacts and unwanted side effects of economic activities that can take the form of a loss of nature or biodiversity, as well as diminished human health, welfare or well-being. Impacts can be intentional or unintentional. Impacts occur across all stage of the life cycle, from extraction to disposal.

Land-based: This refers to any activity that takes place either fully or partly on land. Activities taking place on both land and sea (such as ports or aquaculture) were considered as land-based in this report.

Natural capital: The natural features (living and non-living – such as coral reefs, mangroves and gravel beds) that underpin human well-being through the production of services that benefit society (such as food, flood protection and materials).

Persistent toxins: Refers to chemical substances persistent in the environment that break down slowly and can accumulate in living organisms. These substances are also capable of travelling long distances through different media.

Pressure: The Panel uses the term pressure to describe environmental pressures. These are pressures caused by human activities (commonly tied to the extraction and transformation of materials and energy) that are changing the state of the environment and leading to negative environmental impacts. Priority environmental pressures identified by the Millennium Ecosystem Assessment are habitat change, pollution with nitrogen and phosphorus, overexploitation of biotic resources such as fisheries and forests, climate change and invasive species.

Resource efficiency: Denotes an overarching term describing the relationship between a valuable outcome and the input of natural resources required to achieve that outcome. It is the general concept of using less resource inputs to achieve the same or improved output (resource input/output). It indicates the effectiveness with which resources are used by individuals, companies, sectors or economies. Resource efficiency can be achieved by increasing resource productivity (value added/resource use) or reducing resource intensity (resource use/value added).

Sedimentation: Refers to the action or process of forming, depositing or reducing sediment, including erosion.

Socioecological System: This describes the idea that social and ecological systems should not be considered as separate, but as a single integrated system that connects society, the economy, politics and the ecosystem (Ostrom, 2009). Through this lens, governing resources requires an understanding of human systems as much as natural systems.

Sustainable Blue Economy: The working definition of a Sustainable Blue Economy adopted in this report is an ocean-based economy that provides equitably distributed social and economic benefits for current and future generations, while restoring and protecting the intrinsic value and functionality of coastal and marine ecosystems and is based on clean technologies and circular material flows (adapted from WWF, 2018).

Turbidity: Denotes the optical property of liquids that measures the scattering and/or absorption of light.

1

INTRODUCTION


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Coastal resources are critical to people, nature and the economy. Coasts provide food, energy and minerals; support cultural, recreation, leisure and health opportunities; and provide space for critical transport and trade infrastructure (Martínez *et al.* 2007; OECD, 2016; Nairobi Statement of Intent 2018). Climate change is negatively impacting coastal ecosystems (particularly the upper water column, coral, wetlands and kelp), the human systems that depend on them (particularly fisheries, tourism and habitat services) and is causing changes to the physical characteristics of the ocean, including rising sea levels, warming waters and acidification (IPCC, 2019). As such, climate change adaptation and disaster risk reduction in coastal areas are key governance considerations.

Coastal resources are a focus for the emerging 'Sustainable Blue Economy' agenda. Whilst there is no globally agreed definition of a Sustainable Blue Economy, the working definition adopted in this report is *an ocean-based economy that provides equitably distributed social and economic benefits for current and future generations, while restoring and protecting the intrinsic value and functionality of coastal and marine ecosystems and is based on clean technologies and circular material flows* (adapted from WWF, 2018). This aligns with the assertion in the Global Resources Outlook (IRP, 2019a) that the decoupling of natural resource use and environmental impacts from economic activity and human well-being is an essential element in the transition to a sustainable future. Selected sustainable blue economy sectors are presented in Figure 2.

Coasts are complex confluences of people, resources and nature. It has long been recognized that a particular challenge in coastal areas, particularly in small island developing States, is the management of land-based activities that have detrimental impacts on coastal resources (Xue, Hong and Charles, 2004; Primavera, 2006; Wilkinson and Salvat, 2012; Halpern *et al.*, 2015). In this report, 'land-based' refers to any activity that takes place either fully or partly on land. As such, activities taking place on both land and sea (such as ports and aquaculture) were considered within the definition of land-based activities.

Examples of impacts on coastal resources arising from land-based activities include mangrove removal to make way for hotel or aquaculture development (which releases stored sediment that smothers nearby delicate coral ecosystems) (Richards and Friess, 2016), nutrient-rich domestic waste discharges from cities that strip oxygen from marine waters suffocating marine life, and protein demand from urban populations pushing 33 per cent of the world's fish stocks to be fished beyond biological sustainability (FAO, 2018a). Many of these pressures are negative externalities of land-based human activities that are not taken into account within existing governance

Figure 2. Selected sustainable blue economy sectors

frameworks (Lu *et al.*, 2018). Plastic packaging, for example, which is used across a range of industries, generates significant environmental impacts in terms of carbon emissions, wastewater and marine debris that are currently unaccounted for in any meaningful way (World Economic Forum *et al.*, 2016).

While there is no formal definition of the area encompassed by the term 'coastal', we used the area defined by a nation's Territorial Sea and Internal Waters area as a guide. The Territorial Sea is the area between a national baseline and 12 nautical miles out to sea, which confers the highest level of resource access under the UN Convention on the Law of the Sea. Internal Waters are the areas landward of a national baseline and typically include estuaries, bays and river mouths. The Territorial Sea and Internal Waters, for most countries, typically contain the greatest concentration of resources and most of the economic activity within a nation's maritime area. However, some flexibility was used to reflect the reality of marine ecological connections. For example, offshore fisheries can rely on fish with a coastal life stage (in mangrove nurseries), which may be affected by land-based activities that can in turn impact the offshore fishery.

Developing more effective approaches to the governance of land-based activities to limit their impacts is therefore key to conserving coastal natural capital and associated services upon which humans depend (Lu *et al.*, 2016). Yet governance responses to coastal resource problems that originate from land remain as difficult as ever to address, and are likely to become more so as the impacts of climate change, such as acidification and warming, take hold (Harley *et al.*, 2006; Lu *et al.*, 2018). These challenges are reflected in the UN Sustainable Development Goals (SDGs) (United Nations, 2015), particularly SDG 14 that aims to achieve the sustainable use of the marine environment and resources. SDG 14 targets include 'preventing and significantly reducing' marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution, by 2025 (target 14.1) and by 2020 to sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts (target 14.2) on the services they provide (including fisheries, aquaculture and tourism). SDG 6 also targets an improvement in water quality by reducing pollution by 2030 (target 6.3), and protection and restoration of water related ecosystems by 2020 (target 6.6).

In parallel, there is an increasing international emphasis on the use of coastal resources to stimulate jobs and innovation through 'sustainable blue economy' policies. The global ocean-based economy is estimated to be worth $3 trillion USD per year, which is five per cent of global GDP (United Nations, 2019). It is widely acknowledged that blue economic growth must not degrade the natural capital upon which it depends nor should it generate an inequitable distribution of benefits. For example, the European strategy to develop its maritime economy is based on the premise that healthy marine ecosystems are more productive and therefore underpin sustainable blue economies. This drive is largely shared by the private sector, which is increasingly seeking to integrate its use of coastal resources with measures to safeguard the coastal environment (Neumann *et al.*, 2017). Achieving the full potential of the blue economy involves recognizing and tackling the negative externalities from land-based activities. Indeed, the recent International Resource Panel (IRP) think piece on land restoration noted co-benefits to the delivery of all SDGs and recommended an integrated landscape approach as key to increasing the total return on land restoration investments (IRP, 2019b).

The transition to a sustainable blue economy is an opportunity to drive towards gender equality in ocean-related employment, leadership, involvement in policymaking and management and research, thereby making a strong contribution to the 2030 Agenda - as advocated during World Oceans Day 2019. In order to fulfil global sustainable blue economy ambitions, there is a need to develop new 'blue' governance systems for coastal areas. These must incorporate the full range of economic sectors that depend upon coastal resources and take account of activities originating on land that affect coastal resources. **The primary aim of the study is therefore to determine appropriate governance approaches to reduce the impact of land-based activities on coastal resources and to support the transition to a sustainable blue economy.** A secondary aim of the study is to test a new method to identify the pathways through which land-based activities impact coastal resources.

To achieve these aims, it is first necessary to understand how large-scale processes drive land-based activities, how these then influence the state of coastal resources and the extent to which blue economy sectors are vulnerable to changes in resource condition or availability. These impact pathways are complex, as they cross the land-sea boundary and operate at multiple spatial scales. The following example illustrates the complexity: human migration to the coastal zone can drive manufacturing growth, which can generate pollution (including plastics) that enters the ocean through surface water runoff or through poor waste and wastewater management practices. This then affects the characteristics of marine ecosystems and influences the state of biodiversity. In turn, this can disadvantage biodiversity-dependent blue economy sectors, such as fisheries.

Each step in the pathway linking population growth to fisheries is typically governed independently, with little consideration of implications for other sectors or activities. This is often further complicated by governance arrangements on land and at sea being entirely unconnected from where impacts are experienced, sometimes in different national or international jurisdictions to those where the impact originated. The impact and governance separation creates challenges when responding to land-based effects on coastal resources. In these situations, the impact pathways pass through multiple governance settings, and this hampers the actions that would be necessary to manage the any negative effects, or indeed, support positive change. Key to overcoming these governance challenges is the ability to determine the linkages between land-based activities and their effects on blue economy sectors, in order to frame and develop appropriately targeted interventions.

Attempts to develop and implement effective governance systems that reflect the connectivity between land-based activities and coastal resources are hindered by three interlinked knowledge gaps: 1) incomplete scientific understanding of the cumulative effects arising from land-based activities and the vulnerability of blue economy sectors to those impacts; 2) a lack of knowledge of the impact pathways that connect land-based activities to coastal resources; and 3) a lack of effective governance frameworks that genuinely take account of the connections between land-based activities and coastal resources, particularly at the national scale. Table 1 demonstrates how this study contributes to each of these knowledge gaps.


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Knowledge gap	Associated challenge(s)	Objective(s) of this study
Scientific knowledge	Scientific studies describing cause and effect relations between land-based activities and coastal resources tend to focus on single resources and/or impacts and ignore complex and cumulative impacts.	• Aggregate and synthesize current scientific knowledge in order to provide a holistic overview of multiple impacts. • Assess the quality and strength of current evidence and highlight gaps in knowledge.
Impact pathways	Most scientific studies and industry assessments do not fully describe impact pathways or assess the cumulative impacts arising from multiple pathways.	• Highlight the pathways through which land-based activities impact coastal resources. • Provide a comprehensive framework through which the cumulative impact pathways of land-based activities upon coastal ecosystems and resources can be assessed.
Governance response	Many governance mechanisms cannot accommodate impact pathways crossing between land and sea.	• Present options for enhanced land-sea governance that recognizes impact pathways crossing between land and sea and that support the transition to a sustainable blue economy.

Table 1. Summary of knowledge gaps and the contribution of this study to filling them

In achieving the objectives set out in Table 1, this study will provide a holistic picture of the effect of land-based activities on coastal resources and propose governance responses to address those effects. The main body of the report presents a global analysis of the multiple pathways through which land-based activities can affect coastal resources (chapters 2 to 4), which is followed by an assessment of the vulnerability of the economic sectors that rely upon coastal resources, with a view to determining implications for the blue economy (chapter 5). The global analysis is enriched by a detailed examination of coastal mineral extraction and aquaculture as examples of land-based activities with significant impacts on coastal resources (chapters 6 and 7), before governance recommendations are developed to better account for the effects of land-based activities on coastal resources and support the transition to a sustainable blue economy (chapter 8). The report does not undertake an economic analysis of the impacts of land-based activities on coastal resources, nor does it consider the financial cost of specific governance options or funding opportunities to meet those costs.

2

METHODS

Maximillian cabinet/Shutterstock

2.1 Analytical framework

The study adopts the Drivers, Pressures, State, Impact, Response (DPSIR) framework as its conceptual underpinning to enable a systems-based analytical approach. This was selected as it provides a globally recognized and scientifically credible framework through which interconnected elements of a complex system can be meaningfully interpreted and (in part) to provide consistency with other International Resource Panel (IRP) reports, the majority of which also use the DPSIR framework. The elements of the DPSIR framework, along with their interpretation in this study, are presented in Table 2 and Figure 3.

Element	Definition
Driver	These are major forces that affect the environment, whether societal (such as energy development and demographics) or natural (such as climatic or oceanographic processes). In this study, drivers relate to the forces that shape the development and scale of relevant land-based activities.
Pressure	These are the human activities that generate stress on the environment. In this study, these are land-based activities that have the potential to affect coastal resources. Pressures can generate stressors that affect the state of coastal resources.
State	This is the condition of the environment, including attributes that are important for society and/or for the functioning of an ecosystem. In this study, state refers to the condition and availability for use of coastal resources, which can be affected by the stressors generated by pressures.
Impact	This is a measure of change in the condition or availability of environmental attributes and the associated availability of benefits to society. In this study, impact relates to how a change in the state of a coastal resource has the potential to affect sustainable blue economy sectors.
Response	These are societal interventions intended to shift a system to deliver desirable outcomes. This typically takes the form of efforts to reduce or remove pressures on the environment. In this study, responses are governance interventions.

Table 2. Components of the DPSIR framework.

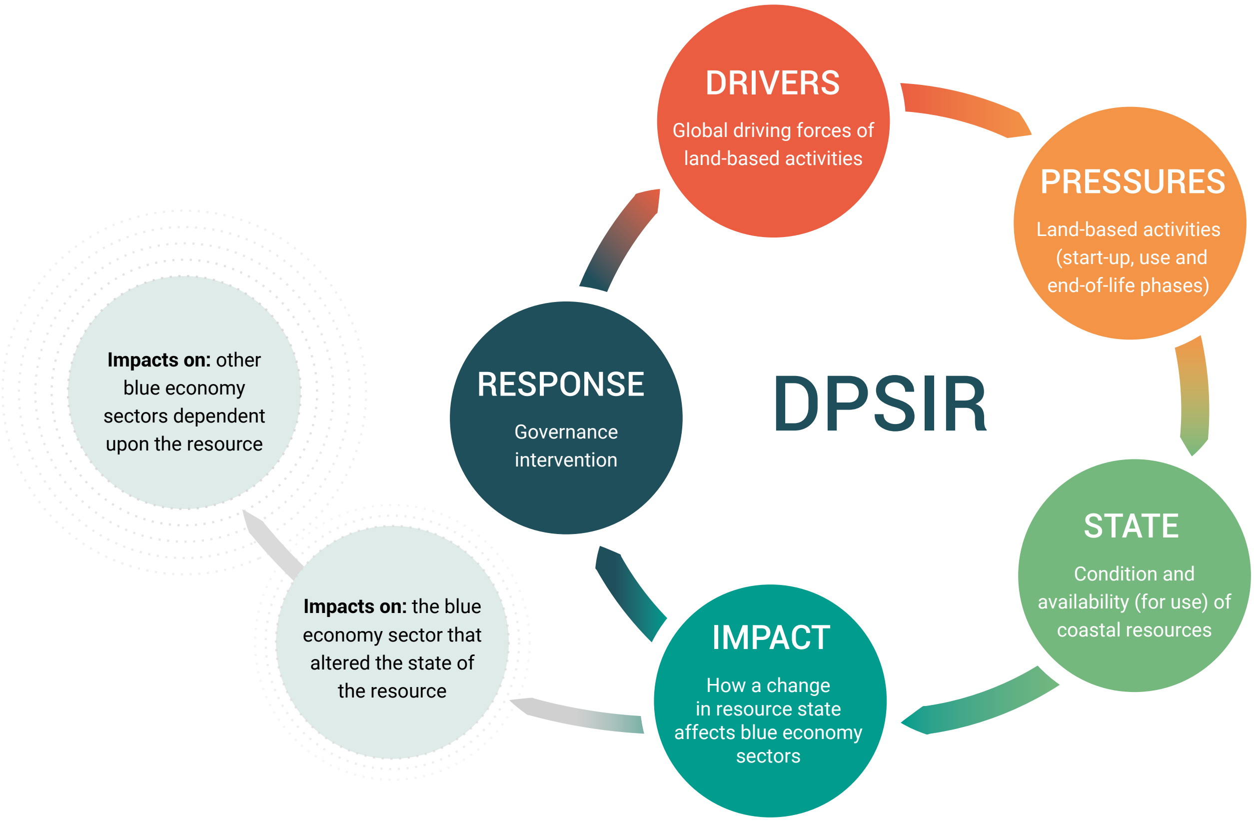


Figure 3. Illustration of the DPSIR framework.

The DPSIR approach was used to structure the study into the following steps:

i. **Identification of global forces driving land-based activities (drivers).** Drivers were identified by reviewing relevant documents including UN Environment Global Environment Outlook reports, UN Environment Frontiers reports, the UN World Ocean Assessment and reports from the World Bank, Food and Agriculture Organization (FAO) and the Organisation for Economic Co-operation and Development (OECD). Drivers particularly relevant to land-based activities and coastal resources were prioritized for inclusion in the study.

ii. **Identification of relevant land-based activities (pressures).** The land-based activities included as pressures were identified by logical extension from the drivers identified in step i plus expert views of their known influence on coastal resources. The resulting list of activities is not exhaustive but captures the land-based activities considered most likely to generate the most significant pressures on coastal resources. Each land-based activity includes consideration of its entire life cycle, including start-up, use and end-of-life phases. Each pressure generates one or more stressors, which in turn have the potential to affect the state of coastal resources.

iii. **Identification of the effects of land-based activities on coastal resources (state).** In order to determine the effects of land-based activities (pressures) on coastal resources (state), a structured analytical process was developed and applied. This consisted of three interconnected analyses: 1) an evidence-based review of the natural stressors (such as sedimentation) and non-natural stressors (such as plastic pollution) generated by each land-based activity; 2) an evidence-based review of how the stressors generated by land-based activities affect the condition and availability of coastal resources; and 3) a synthesis of steps 1 and 2 to directly demonstrate the effects of land-based activities on coastal resources.

iv. **Identification of how coastal resource change affects sustainable blue economy sectors (impact).** An assessment of the dependency of relevant sustainable blue economy sectors on coastal resources was undertaken based on published evidence and expert views. The level of dependency allowed the vulnerability of each sector to coastal resource change (driven by land-based activities) to be determined.

v. **Case study analysis of aquaculture and mineral extraction.** Two detailed case studies were undertaken to further explore the connections between land-based activities and coastal resources. While recognizing that both aquaculture and mineral extraction can occur on land or at sea, in this study they were considered as land-based activities. The case studies allowed for more detailed consideration of governance approaches with the potential to ensure that the effects of land-based activities on coastal resources are fully recognized and addressed. The case studies also enabled the analytical method to be tested within two sector-specific contexts.

vi. **Identification of governance options to reduce the effects of land-based activities on selected sustainable blue economy sectors (response).** An analysis of existing and relevant land-sea governance approaches was undertaken to determine plausible governance approaches that take account of the multiple connections between land-based activities, coastal resources and sectors within the sustainable blue economy. This analysis, along with the governance analysis in the case study chapters, provides the basis for the governance recommendations arising from this study.

These steps and the associated data collection process (described in section 2.2) were developed at a face-to-face international expert workshop held in Beijing in January 2016 and approved by a meeting of the IRP in 2017. Each step of the method has received extensive peer review. The analysis described in stages i to iv was reviewed and validated during two international expert online workshops in mid-2018, and the case study reviews were refined and validated at a workshop in Beijing in January 2019. This report was independently and anonymously peer reviewed, with over 340 individual comments received and addressed.

2.2 Data collection and analysis

This study drew the vast majority of its evidence base from the published scientific literature, supplemented by expert opinion in the event of evidence gaps. Analytical steps i to vi (presented in section 2.1) required identification and characterization of the relationship between every land-based activity (such as tourism or forestry), the stressors generated by each of those activities (including sedimentation or release of toxins) and the effect of each stressor on every coastal resource (such as change in resource quality or availability). This involved undertaking individual evidence reviews to determine the scale and direction of each relationship.

In practical terms, each review involved searching online databases and catalogues to find relevant published evidence. Multiple databases were searched to ensure full coverage of the published evidence, with emphasis on the Web of Science Core Collection (due to its high quality standards). Careful consideration was given to the choice of keywords and the design of each search to ensure that each one was as specific as possible. Moreover, recognizing that oceanographic processes vary depending on a study site's depth and distance to the coastline, studies from a variety of marine environments were included, with a general focus on environments within Internal Waters and the Territorial Sea. Finally, as is common in this type of research, each evidence search was time-limited in order to ensure consistency between searches, to make allowances for the different scales of available evidence and to ensure that the research process was not skewed towards (or away from) particular topics. In total, 253 structured time-limited searches were undertaken – one for each relationship assessed.

The studies found through each search were assessed (not in a time limited manner) in order to determine the quality and robustness of their methodology and findings. The appropriateness of the data collection and analytical methods, as well as the robustness of the results and conclusions, were used to determine the credibility of the evidence. In order to evaluate the overall strength of the body of evidence, the literature gathered through each review was assessed according to 1) the size of the body of evidence (as determined by search results) described as being relatively large, medium or small; and 2) the quality of the body of evidence using an average rating that assessed the quality and robustness of the methodologies used in the underlying evidence base. The classification system of the evidence included in this study is presented in Table 3. Studies and reports deemed to be of low quality were not included in the study.

Strength of evidence	Definition	What it means	
Very strong	High quality body of evidence, large in size, consistent and contextually relevant.	We are very confident that the intervention does or does not have the effect anticipated. The body of evidence is very diverse and highly credible, with the findings convincing and stable.	Included in study
Strong	High quality body of evidence, large or medium in size, highly or moderately consistent and contextually relevant.	We are confident that the intervention does or does not have the effect anticipated. The body of evidence is diverse and credible, with the findings convincing and stable.	
Medium	Moderate quality studies, medium size evidence body, moderate level of consistency. Studies may or may not be contextually relevant.	We believe that the intervention may or may not have the effect anticipated. The body of evidence displays some significant shortcomings. There are reasons to think that contextual differences may unpredictably and substantially affect intervention outcomes.	
Limited	Moderate-to-low quality studies, medium size evidence body, low levels of consistency. Studies may or may not be contextually relevant.	We believe that the intervention may or may not have the effect anticipated. The body of evidence displays very significant shortcomings. There multiple are reasons to think that contextual differences may substantially affect intervention outcomes.	Not included in study
No evidence	No/few studies exist.	There is no plausible evidence that the intervention does/does not have the effect indicated.	

Table 3. Criteria used to assess the strength of the evidence used in the DPSIR analysis

2.3 Limitations and uncertainties

When interpreting the findings, the following cautions and limitations should be considered:

- **The analysis is largely based on evidence derived from the published scientific literature:** As with any study that draws heavily from the academic literature, the relationships and assertions presented within this study are constrained by the reliability of the underlying evidence base. To offset this risk, several steps were taken: 1) stringent quality controls were applied to ensure that only relevant and high-quality evidence was included in the study; 2) the evidence was compiled and reviewed by knowledgeable scientists who could exercise their professional judgement to identify and filter out errant evidence; 3) the evidence included in the study (over 1000 individual sources) represents a wide variety of authors, institutions, locations and methods, and systematic bias or error is therefore unlikely; and 4) within the framework of the study, two expert workshops were held to independently review and validate the analysis of the evidence reviews.
- **Complex relationships between impact and response:** Coastal environments, and the dynamics of the resources they contain, are extremely complex. Therefore, many of the relationships assessed may be non-linear, contain tipping points and thresholds and involve a combination of additive, synergistic and antagonistic relationships. In addition, the nature of the relationships is often taxa specific, may vary through space and time and may be enhanced or dampened by natural variability in conditions. Such complexity can lead to unpredictable and abrupt changes in ecosystems and resources that are difficult to predict and explain. As such, the simple summary of the relationship between individual pressures, stressors and state masks considerable complexity. Where possible, this variation has been taken into account in the assessment of the relationship between activities, stressors and coastal resources, using the professional judgement of the research team and independent experts.
- **Space, time, location and intensity of activities and stressors:** The influence of a stressor will vary depending upon many factors including the existing condition of the impacted resource (for instance, if it is recovering from previous impacts); the intensity, duration, frequency and spatial scale of the perturbation; and if there are other stressors impacting it at the same time. As the study seeks to provide globally relevant findings, it is possible that the full range of geographic variation has not been captured and regional variation may be underrepresented, particularly as a high proportion of studies originate in the global North. However, where possible, this variation has been taken into account in the assessment of the relationship between activities, stressors and coastal resources, using the professional judgement of the above-mentioned researchers and specialists.
- **Selection and classification of activities, stressors and resources:** While the relationships and pathways considered in this study were selected according to published literature and expert opinion in order to cover the most prevalent and damaging ones, the list of possible activities, stressors and resources is vast. As such, additional impact pathways will exist but are outside the scope of this study. In order to undertake meaningful analysis of individual land-based activities and to avoid double counting of impacts, it was necessary to subdivide certain activities. For example, 'tourism and recreation' could be interpreted to be extremely multifaceted, including transport, infrastructure, food, energy and sewerage disposal. However, in our analysis, sewerage/waste discharge and infrastructure were considered to be such significant cross-cutting issues that they required their own activity class. As such, there is a possible risk of under-representing the impacts of tourism and recreation on coastal resources without taking into account the other elements of the activity. Where appropriate, this is noted in the discussion of the results.
- **Scientific knowledge and bias:** It is expensive, time consuming and logistically challenging to collect field data from multiple ecosystems in order to accurately represent how coastal resources respond to multiple pressures. Therefore, there remains uncertainty about some of the relationships and significant gaps and potential biases in our understanding – principally in relation to the impact of activities and stressors upon abiotic or newly exploited resources.

Unsplash/Steve Halama

3 DRIVERS OF COASTAL CHANGE

Unsplash/Jeff Hilbrand

3.1 Introduction

The aim of this chapter is to identify the principal influences driving coastal change. Drivers are the factors, be they natural or human-induced, that prompt broader changes. Drivers may have an explicit influence on ecosystem processes or a more diffuse influence by altering the scale or rate of change. As all drivers are complex, vary in space and time and rarely act in isolation, it is seldom possible to identify causal links between specific drivers and specific ecosystem changes. As such, for the sake of clarity, we examined each driver separately, recognizing that this is a simplification and that driving forces are usually multiple and interactive. While the COVID-19 pandemic may influence aspects of the projections presented in this chapter, the overall direction of the drivers themselves is unlikely to change fundamentally. As well as setting the broader setting of this study, the following drivers were used to inform the choice of land-based activities (pressures in the DPSIR framework) carried into the remainder of the study.

3.2 Drivers

Urbanization

Over the last six decades, the global urban population increased rapidly from 30 per cent in 1950 to 54 per cent in 2014 (Figure 4). By 2030, 60 per cent of the world's population is expected to live in urban areas (UNDESA Population Division, 2015). While urbanization is a global trend, the level and rate of urbanization varies between regions. The fastest increase in urban population is expected to occur in Africa and Asia, in particular in China, India and Nigeria (UNDESA Population Division, 2015). The main contributors to urbanization are natural increases of urban populations, migration from rural areas and the annexation or reclassification of previously rural areas.

The World Ocean Assessment (UN, 2016) found that 13 per cent of the global urban population lives in coastal areas. This includes many of the world's largest cities and megacities, such as Rio de Janeiro, New York, Mumbai, Dhaka, Tokyo, Lagos and Cairo (Inniss *et al.*, 2016). The urban population of coastal cities is expected to continue to grow. For example, in the Caribbean, the coastal urban population is expected to increase to 75 per cent by 2025 (UNEP, 2016c). Similarly, in the East Asia and Pacific region, the coastal urban population is projected to grow by an additional 325 million people by 2025 (UNEP, 2016b). In Africa, home to six of the ten countries with the fastest urbanization rates, many of these growing cities lie on the coast (UNEP, 2016a). Urbanization therefore directly contributes to coastal infrastructure, ports and harbour development and potentially land reclamation. Urbanization has direct effects on biodiversity and the state of the coastal environment, and this inherently translates into socioeconomic vulnerability.

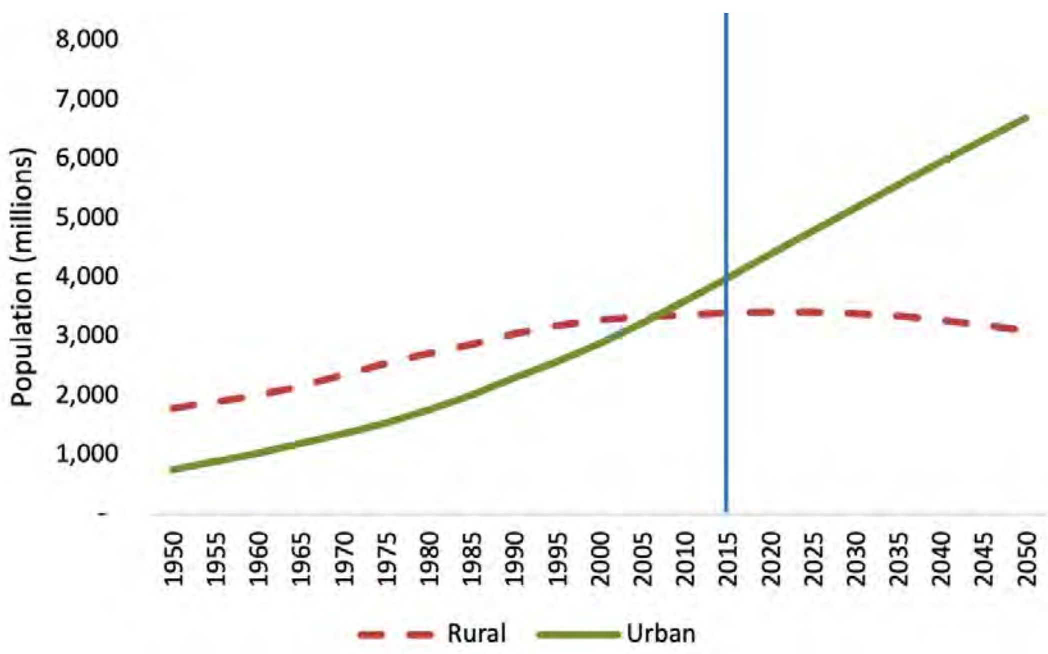


Figure 4. The world's urban and rural populations, 1950-2050 (Source: United Nations, 2015).

Population growth

By 2030, the global population is projected to reach 8.6 billion people (United Nations, 2019). Over half of the projected population growth is expected to occur in Africa, while Europe is the only region where population is predicted to be smaller in 2050 than in 2017 (United Nations, 2019). It is important to note that global demographic change, particularly falling birth rates, is causing a slowing of population growth rates and may in time reduce the pressures associated with population growth (UNEP, 2012), though overall population is still projected to grow by 2100 (Figure 5).

The continued growth of the global population puts increasing pressure on the planet's coastal and marine resources. In 2017, nearly 2.4 billion people (about 40 per cent of the world's population) lived within 100 km of the coast (United Nations, 2017). Population growth is a key driver for several land-based activities related to the provision of food, water and energy. These include fishing, aquaculture, agriculture, deforestation and salt extraction, as well as oil and gas production and marine renewable energy production (United Nations, 2016). With a large part of the world's population already living in coastal areas, global population growth - as with urbanization - is a driver for coastal infrastructure development and associated activities such as ports and harbours, land reclamation, mining and wastewater discharge, as well as tourism and recreation.

Industrialization

Industrialization (or the rapid development of industries in a country or region on a large scale, often in association with urbanization) has changed the Earth significantly over the last 200 years. Global economic output in the twentieth century grew 20 fold (UNEP, 2012). Continuing discovery and development of better and more efficient technologies have ensured continued industrialization in the developed world, while developing countries are experiencing widespread industrialization as their capacity and economies grow. Globalization is a contributing factor to industrialization in developing countries, as international companies move their production to where labour is cheapest. While the projected growth of every industry to 2030 is different, as an illustration, construction industry output is forecast to grow by 85 per cent to USD $15.5 trillion worldwide by 2030, with China, India and the United States

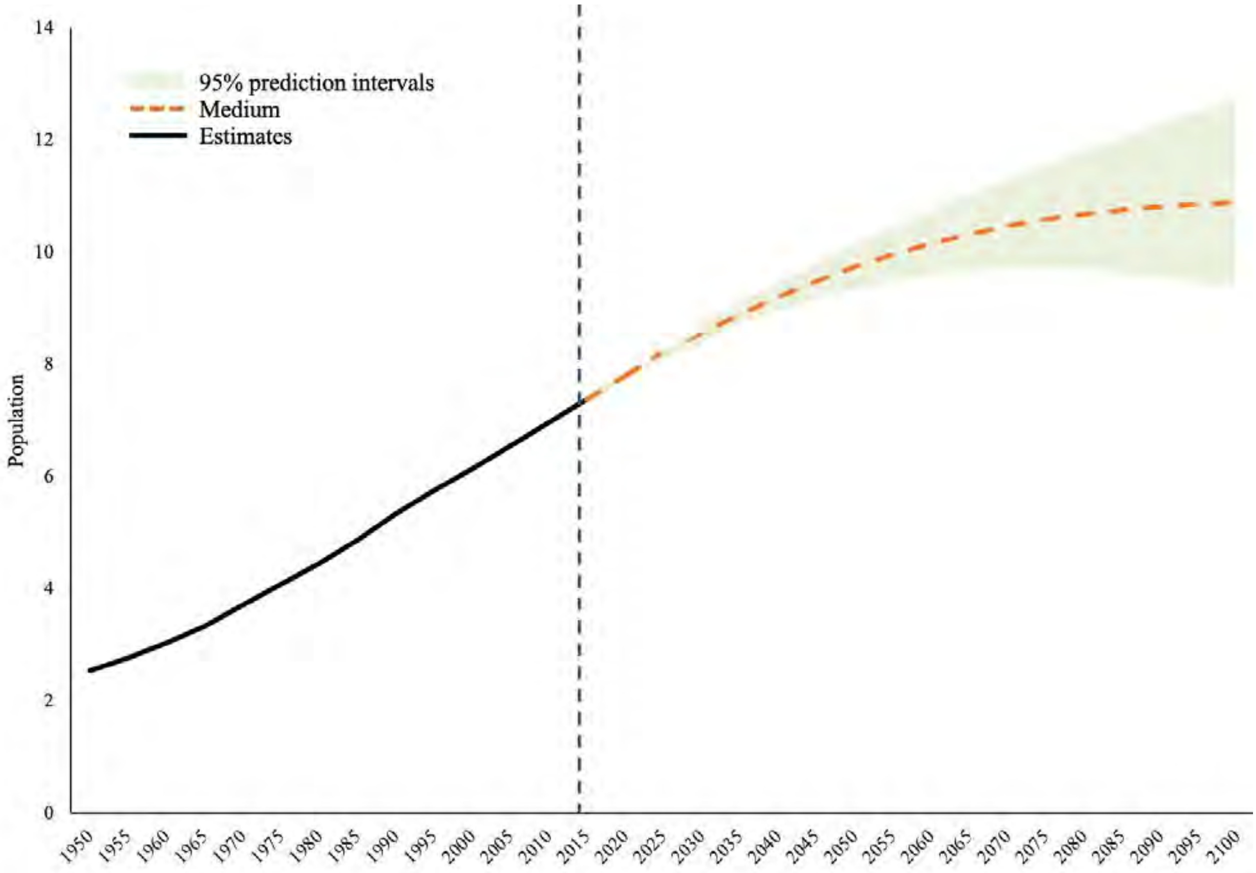


Figure 5. Global population trends – estimates for 1950 to 2015 and projections for 2015 to 2100 (Source: United Nations, 2019).

together accounting for 57 per cent of all growth (Global Construction Perspectives and Oxford Economics, 2015), although the COVID-19 pandemic sets these projections in an uncertain light.

Increasing technological capability facilitates growth across all industries, as equipment and machines become cheaper and more efficient. Industrialization of agriculture and forestry allows farming and forestry practices to take place across larger areas for less effort, particularly in developing countries where these sectors are shifting away from manual labour and where food security is a priority. Land clearance on an industrial scale paves the way for agriculture, aquaculture and other land-use changes such as urban expansion, building infrastructure, plants and factories. Industrialization of the global fishing fleet has expanded catch capabilities and has significantly reduced fish stocks on a global scale (Thurstan *et al*., 2010; Anticamara *et al*., 2011). New technologies have facilitated staggering growth of the extractive industries, for example rock drilling capacity has increased exponentially throughout the twentieth century (ICMM, 2012). Space, transportation and infrastructure required for industrial goods, as well as technological improvements, are linked to the expansion of the shipping industry and the building of ports and harbours. Lastly, industrialization has facilitated, and is a driver of, land reclamation, with over 90 per cent of new land reclamation taking place in China (an average of 120km2 per year) primarily for commercial or residential use (Duan *et al*., 2016).

Climate change

Global climate change has numerous, widespread impacts on human and ecological systems that act in isolation and cumulatively (Inniss *et al*., 2016; Masson-Delmotte *et al*., 2018), as well as being a key driver of change in many of the land-based activities that exert pressure on coastal and marine ecosystems. Shifts and changes in seasons and rainfall patterns require changes in agricultural practices, while climate change mitigation is driving reforestation initiatives and marine renewable energy development. Changing weather patterns increase volatility in the salt-extraction industry, which provides rock salt for de-icing and food preservation, amongst other uses. Increasing ocean temperatures and acidification are already affecting fish stock compositions and distributions, as well as driving change in fishing and aquaculture activities. Accelerated sea level rises and the amplification of extreme storm events are a threat to low-lying coastlines through erosion and flooding and are a driver for the development of coastal defense infrastructure, while sea level rise can also cause increased saline incursion in soil (damaging agricultural productivity). Increasingly frequent and intense storms also pose a risk for submarine cables. Finally, the melting of the Arctic sea ice is opening new shipping routes between the Atlantic and the Pacific Oceans.


Piyaset/shutterstock

Migration

Humans have always migrated, but with economic growth and major developments in international transportation over the last century, migration has significantly increased. There are many reasons for migration including political, environmental (especially due to climate change) and economic. The World Cities Report 2016 highlighted international migration as a major issue for cities, while rural-to-urban migration was a major driver of city growth in the twentieth century and is a major driver of city growth in Africa (UN-Habitat, 2016). Currently, the largest receivers of international migrants are the United States of America, Saudi Arabia, Germany, Russian Federation, United Kingdom of Great Britain and Northern Ireland and United Arab Emirates, while the originating countries for most international migrants are India, Mexico, China, Russian Federation and Syrian Arab Republic (UNDESA, 2019).

Within-region migration is also significant. In 2011, for example, 31 per cent of the urban population in China was estimated to represent within-country rural-urban migration (UN Habitat, 2016). Migration is far from affecting exclusively coastal areas, particularly in population-dense Europe, but is a significant contributor to coastal population growth and urbanization (Neumann *et al.*, 2015). Between 1970 and 2000, nearly all coastal ecosystems, as categorized by the Millennium Ecosystem Assessment, experienced net in-migration (de Sherbinin *et al.*, 2012). Migration is a significant contributor to increasing population and urbanization in the coastal zone, particularly cities, which contribute to urban expansion and the development of coastal infrastructure.

Increased personal wealth and living standards

Global Gross Domestic Product (GDP) has grown every year since 1961, except for 2009 when it shrank by 1.7 per cent following the financial crash of 2008. As a result of the COVID-19 pandemic, it is thought that 2020 may also see a reduction in GDP far greater than in 2009. Global personal wealth has grown every year since 2000, with the contribution to growth from lower income economies rising as personal wealth increases in less developed countries. Increased personal wealth and the resulting rise in living standards have pushed up consumption of energy, food and luxury goods. Expansion of these sectors, driven by higher personal wealth, will increase the pressures on coastal resources and the marine environment. Per-capita food consumption will rise through 2017-2026, though at a lower rate than the previous decade (OECD & FAO, 2017), while an upturn in online sales and associated packaging increases the amount of material reaching landfill. This will increase pressure on the environment from agriculture, water abstraction, forestry, aquaculture and fishing. Demand for food-grade salt will also surge, driving up activity in the salt extraction industry.

The World Energy Outlook 2016 predicts a 30 per cent rise in global energy demand to 2040, with the energy sector's carbon emissions also continuing to grow (IEA, 2016). In the 2040 scenario, renewable energy contributes to nearly 60 per cent of power generation, with the majority coming from wind and solar energy. The marine renewables sector is expected to continue to grow, as is offshore oil and gas extraction. Submarine cables and pipelines, which form the infrastructure of these industries, will increase in number. Rising personal wealth will also drive up tourism and recreation, particularly in developing countries. However, there are competing views. Growing youth and public support for climate action may affect energy demand, as might possible changes in public attitude to the environment arising from COVID-19, as well as more plausible scenarios emphasizing sustainable energy options. For example, the International Resource Panel 'Towards Sustainability' scenario proposes interventions that slow the growth of resource use, while incomes and other well-being indicators improve and key environmental pressures fall (IRP, 2019a).

Globalization

Globalization can be defined as the increasing linkages between different parts of the world through trade, communication, finance and technology. Globalization makes it possible for trends in other drivers to generate pressure in specific parts of the world. Following the transport and technology boom of the twentieth century and opening of global markets, globalization has become a prominent feature of modern society. However, many are starting to argue that increasing isolationism within some countries marks a turn in the tide of globalization; world trade is no longer growing at the same rate as the global economy (Wolf, 2016) and measures of globalization are starting to plateau, as demonstrated in Figure 6. The trend towards globalization may be further slowed by public health measures applied to international trading and the movement of goods designed to prevent the further spread or resurgence of COVID-19.

Globalization allows commodity production in developed countries to be relocated to developing countries, prompting new industrial plants and factories to be built. Between 1995 and 2014, the percentage contributed by developing countries to global exports rose from 12 to 31 per cent (Bertelsmann, 2016). Globalization drives expansion of the shipping industry, including port and harbour facilities, land reclamation and other coastal infrastructure development. Though globalization may be slowing, the shipping industry continues to thrive and is expected to continue its expansion to 2030 (Lloyd's Register, QineticQ and University of Strathclyde, 2013).

The drivers of coastal change presented in this chapter are summarized in Figure 7.

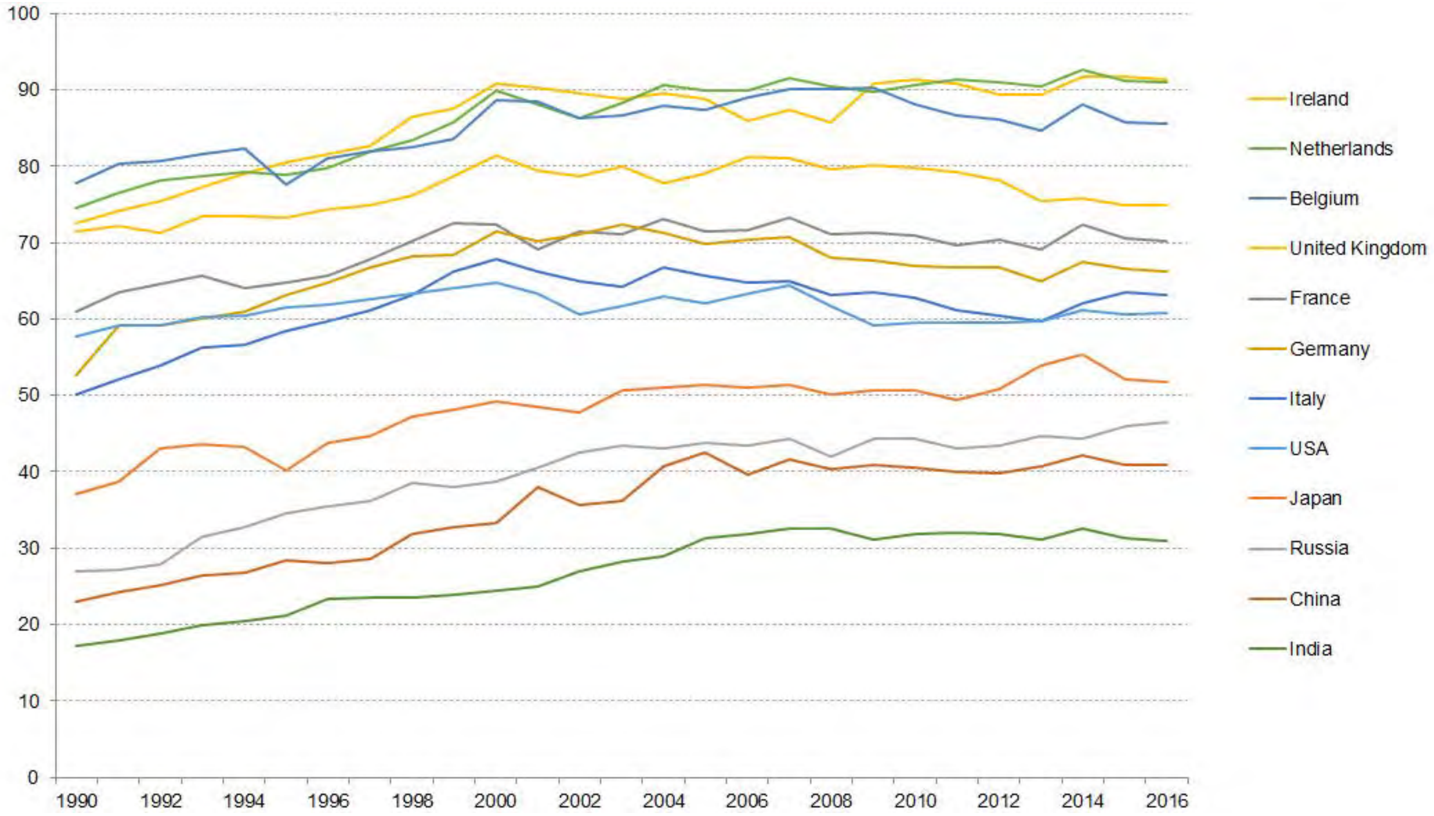


Figure 6. Developments in the globalization index for selected countries for the period 1990-2014. (Source: Bertelsmann, 2018).

Figure 7. Summary of drivers of coastal change

3.3 Summary of pressures

Pressures are human land-based activities that cause environmental stressors that, in turn, have the potential to affect the condition of coastal resources. Based on the review of global drivers presented in section 3.2 and the canvassing of expert opinion, the land-based activities most likely to generate effects on coastal resources are presented in Table 4. Inevitably, some land-based activities were omitted as separate pressures, including transport and groundwater exploitation, although both were considered as elements of other pressures. It should be noted that each land-based activity includes consideration of its life cycle, including start-up, use and end-of-life phases. This means that, for coastal hotels for example, the construction, use (solid waste management, water and food use and employment) and end-of-life treatment (including demolition) would be included in the 'tourism and recreation' category.

Land based activity	Definition
Agriculture	Farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool and other products.
Forestry (and deforestation)	Stand-level forestry operations including site preparation, drainage, ash return, planting, thinning, fertilizing, fire prevention, final felling, harvesting and terrain transport.
Sewage and waste discharge	Human sewage discharged into coastal waters from terrestrial sewage processing plants. Waste discharge includes liquid, solid and hazardous waste discharge from domestic, industrial or commercial activity, including wastewater and leakage and leachate from coastal landfills and open dumps.
Industry	Includes chemical plants, ore processing and metal smelters, paper manufacturing, incinerators and fertilizer production.
Coastal infrastructure	Infrastructure aspects of coastal development, specifically beachfront construction of buildings, houses, piers, harbours, seawalls, roads, railways and airports.
Land reclamation	Encompasses beach replenishment, the creation of artificial land and islands and damming of coastal wetlands.
Ports and harbours	Includes the construction and operation of large-scale industrial ports and small local harbours.
Aquaculture	Includes all freshwater and coastal aquaculture systems. It does not include offshore or entirely marine aquaculture activities.
Salt extraction	Includes conventional shaft mining for rock salt, brine, vacuum pan and open pan production methods, as well as salt produced as a by-product of desalination.
Coastal aggregate mining	Sand or gravel mined or extracted, at least partially on land, in coastal areas.
Other coastal mining	Collective term for the mining, processing and smelting of any mineral resource in coastal areas, except aggregate.
Tourism and recreation	Any tourism or recreational activities occurring in the coastal area, for example sport fishing, diving, snorkelling and dedicated infrastructure, such as hotels.

Table 4. Land-based activities included in this study


Unsplash/Angela Compagnone

4

THE EFFECT OF LAND-BASED ACTIVITIES ON COASTAL RESOURCES


Unsplash/Dustan Woodhouse

4.1 Introduction

The aim of this chapter is to determine effect pathways between land-based activities and coastal resources. In order to determine the effects of land-based activities on coastal resources, it is necessary to consider the natural and non-natural stressors generated by land-based activities that potentially affect coastal resources. The land-based activities included in this analysis are not restricted to coastal areas as we recognize that land-based activities taking place at significant distances from the coast (such as agriculture) may generate effects on coastal resources. The analysis presented in this chapter therefore has three steps:

- Analysis of stressors arising from each land-based activity;
- Analysis of how each stressor influences coastal resources;
- Summary of the impact pathways between land-based activities and coastal resources.

In the context of the DPSIR framework, this chapter connects the pressures generated by land-based activities to the state of coastal resources, with the stressors as the explanatory connector.

4.2 Stressors arising from each land-based activity

Stressors are the physical, chemical or biotic characteristics of the environment that can be influenced by land-based activities and that, in turn, have the potential to change the condition of any characteristic (living or non-living) of a coastal ecosystem. Drawing upon relevant literature related to the land-based activities identified in chapter 3, eight natural stressors (naturally occurring properties of the ecosystem that can be altered by human activities) and three non-natural stressors (entirely introduced into coastal ecosystems by humans) were identified (Tables 5 and 6). The choice of stressors was reviewed and confirmed through consultation with experts and during two online workshops.

Natural stressors	Definition
Sedimentation	The action or process of creating, depositing or reducing sediment, including erosion.
Turbidity	An optical property of liquids that measures the scattering and/or absorption of light due to material suspended in solution.
Nitrogen	The concentration of organic nitrogen in seawater.
Phosphorus	The concentration of organic phosphorus in seawater.
Temperature	Sea surface temperature and local water temperature.
Salinity	The concentration of dissolved salt in the water.
Current	Tidal currents, coastal currents (longshore currents, rip currents and upwelling) and surface marine currents.
Dissolved oxygen	The amount of oxygen dissolved (and hence available to sustain marine life) in the water.

Table 5. Natural stressors included in this study

Non-natural stressors	Definition
Persistent toxins	Polychlorinated biphenyls, heavy metals (copper, nickel, iron, zinc, mercury and methylmercury), persistent organic pollutant, toxic chemicals, dioxins, oil pollution (oil discharge, oil slick, accidental spills, oil extraction and operational oil discharge), Non-methane volatile organic compounds (nmVOC) Polycyclic aromatic hydrocarbons (PAHs), pesticides, antibiotics, Polychlorinated dibenzodioxins (PCDDs), Polychlorinated dibenzofurans (PCDFs), dichlorodiphenyltrichloroethane (DDT), Polychlorinated dibenzodioxins and furans.
Plastics and other debris	Macroplastics, microplastics, microbeads, plastic materials, beach litter, plastic litter, plastic pellets, plastic granules, plastic scrubbers, drift plastic, fishing litter and shipping litter.
Introduced invasive species	Any organism that is introduced into a new marine environment where it either is non-native or in which it is proliferating extremely rapidly at the expense of other organisms. Species introduced through ballast water, biofouling, the aquarium trade and other sources are also considered.

Table 6. Non-natural stressors included in this study

In order to determine and quantify the linkages between land-based activities (pressures) and stressors in a systematic manner, a matrix was developed showing how each stressor could be influenced by each land-based activity (Tables 7 and 8). The matrix was constructed using the following approach:

- For each of the 132 possible activity-stressor relationships (each cell of the matrix), one hour was spent searching for literature using the Web of Science Core Collection and ordering the results by relevance. A total of 697 papers were reviewed (full details in Technical Annex www.resourcepanel.org/reports/governing-coastal-resources). When relevant peer-reviewed literature was unavailable, grey literature and literature from industrial bodies was consulted.
- Based on the evidence obtained from the time-limited search, each activity-stressor relationship was characterized according to the strength of the influence of the activity on the stressor (using the categorization high, medium, low, no impact found or no studies found) and the direction of the influence found (using the categorization increase; decrease; neutral; and not applicable).
- Finally, the overall strength of the evidence was determined according to its size, quality and consistency using the method described in chapter 2.
- To calculate an average influence of each land-based activity on each stressor, a weighting was attributed to each activity-stressor relationship using the simple system of 3 for a high impact, 2 for a medium impact, 1 for a small impact and 0 where no impact was found. As each land-based activity can influence 11 potential stressors, the maximum influence of a land-based activity is 33 (11 x 3). The cumulative relationship between land-based activities and stressors is shown in Table 8.

	Stressors										
	Natural								*Non-natural*		
Land-based activity	Sedimentation	Turbidity	Nitrogen	Phosphorus	Temperature	Salinity	Current	Dissolved oxygen	Persistent toxins	Plastics and other debris	Invasive species
Agriculture	↑	↑	↑	↑	*N/A*	↑	*N/A*	↓	↑	↑	*N/A*
Forestry	*0*	↑	↑	↑	*N/A*	*N/A*	↓	*0*	↑	↑	*N/A*
Sewage discharge	↑	↑	↑	↑	*N/A*	*N/A*	*N/A*	↓	↑	↑	↑
Industrial plants and factories	*0*	↑	↑	↑	↑	*N/A*	*0*	↓	↑	↑	↑
Coastal infrastructure	↑	↑	*0*	*	*0*	*0*	*0*	↑	↑	↑	↑
Land reclamation	↑	↑	↑	*N/A*	*	*	*0*	↓	↑	↑	↑
Ports and harbours	↑	↑	↑	↑	*N/A*	↑	*0*	↓	↑	↑	↑
Aquaculture	↑	↑	↑	↑	*0*	*0*	↓	↓	↑	↑	↑
Salt extraction	↑	↑	↑	*N/A*	↑	*0*	*0*	↓	↑	*N/A*	*N/A*
Coastal aggregate mining	*0*	↑	↑	↑	*N/A*	*N/A*	*0*	↓	↑	*N/A*	*N/A*
Other coastal mining	↑	↑	↑	↑	*N/A*	*N/A*	*N/A*	*N/A*	↑	*N/A*	*N/A*
Tourism and recreation	↑	↑	↑	↑	*N/A*	*N/A*	*N/A*	*N/A*	↑	↑	↑

Key			
Strength of impact			**Direction of impact**
(red)	*High*	↑	*Increase*
(yellow)	*Medium*	↓	*Decrease*
(green)	*Low*	*0*	*Neutral*
N/A	*No impact*		
*	*No studies found*		

Table 7. The influence of land-based activities on stressors

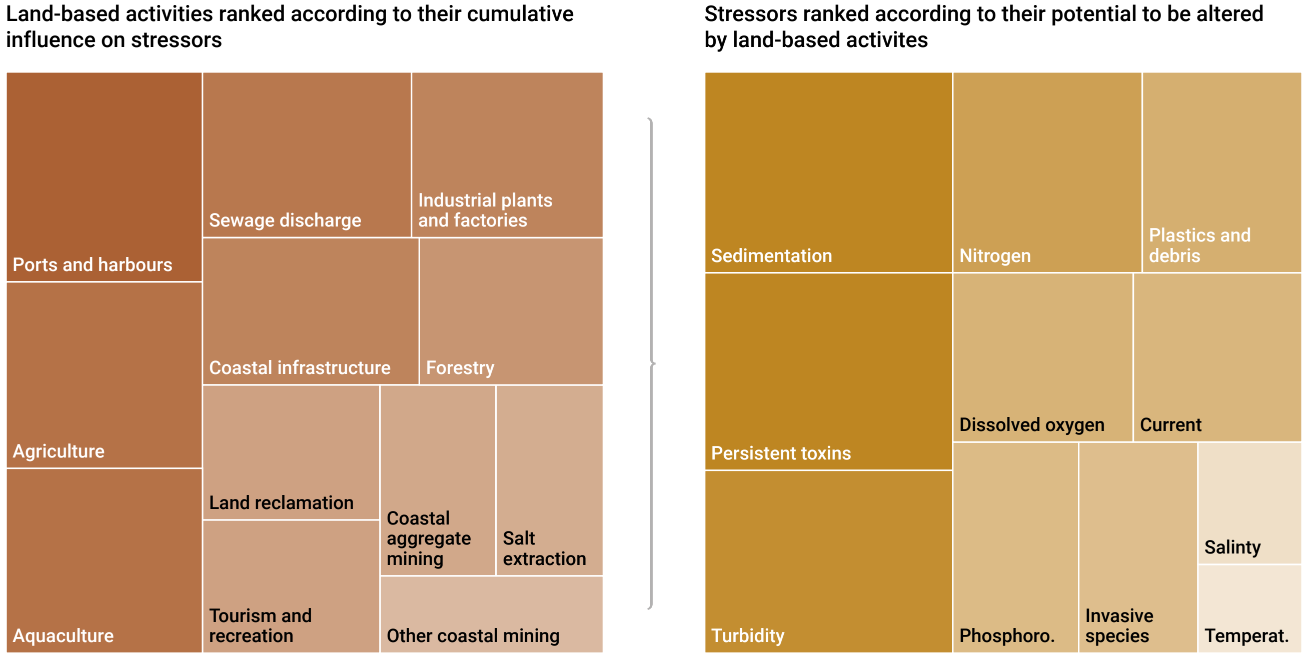


Table 8. Ranked cumulative relationship between land-based activities and stressors

Table 8 shows the cumulative influence on stressors of each land-based activity. Ports and harbours were found to have the greatest influence upon stressors. Through port construction and operation, sediment, turbidity and current patterns are altered and there is the potential to introduce invasive species through ballast water exchange. Roca *et al*. (2014) showed that harbour construction can cause an increase in sediment and turbidity, which only returned to normal levels up to 15 months after construction ended and which had a negative impact on local seagrass meadows. Port operations and ship engines create noise pollution and ship engines generate substantial pollutants.

Agriculture was found to have a strong influence on stressors, particularly through chemical leaching from fertilizer applied to fields, including nitrogen, phosphorus and persistent toxins. Similarly, chemical discharges and waste from aquaculture resulted in a high stressor profile. As well as increasing nitrogen and phosphorus concentrations, sewage discharge strongly influenced dissolved oxygen and plastics stressors. Coastal infrastructure, including housing, was a significant source of plastics. The influence of tourism and recreation on stressors was comparatively limited, mainly because it has limited linkages to the physical marine characteristics (current, salinity and temperature), although its contribution to other stressors is substantial (particularly plastics and other toxins).

4.3 The effects of stressors on coastal resources

The next stage of the analysis was to synthesize available evidence to determine the impact pathways between stressors identified in section 4.2 and coastal resources. This provides the critical link between land-based activities and the condition of coastal resources. The coastal resources included in this study reflect globally relevant resources that underpin conventional blue economy sectors (such as tourism) and newer resource sectors (including marine genetic resources). The coastal resources included in this study are divided into abiotic and biotic coastal resources and are presented in tables 9 and 10, respectively.

In order to determine and quantify the linkages between stressors and coastal resources in a systematic manner, a matrix was developed showing how each coastal resource could be influenced by each stressor (Table 11). The matrix was constructed using the following approach:

- For each of the 121 possible stressor-resource relationships (each cell of the matrix), one hour was spent searching the Web of Science core collection and ordering the results by relevance. A total of 326 papers were reviewed (full details in Technical Annex www.resourcepanel.org/reports/governing-coastal-resources). When relevant peer-reviewed literature was unavailable, grey literature and literature from industrial bodies was consulted.
- Based on the evidence obtained from the time-limited search, each stressor-resource relationship was characterized according to the strength of the influence of the activity on the stressor (using the categorization high, medium, low, no impact found, or no studies found) and the direction of the influence found (using the categorization increase; decrease; neutral; and not applicable).
- Finally, the overall strength of the evidence was determined according to its size, quality and consistency using the method outlined in chapter 2.
- To calculate an average influence of each stressor on each coastal resource, a weighting was attributed to each activity-stressor relationship using the simple system of 3 for a high impact, 2 for a medium impact, 1 for a small impact and 0 for no impact found. As each stressor activity can influence 11 coastal resources, the maximum influence of a stressor is 33 (11 x 3). The cumulative relationship between land stressors and coastal resources is ranked shown in Table 12.

Abiotic resource	Definition
Aggregates	Coastal aggregate supplies (sand and gravel) are important to the economy, particularly the construction industry, exports and coastal defenses.
Coastal minerals	Coastal minerals are minerals extracted from the coastal zone, including limestone, dolomite, amber, diamond and iron ore.
Renewables	Marine renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale.
Oil and gas	Oil and gas are fossil fuels used as a source of energy for heating, cooking and electricity generation. They are also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.
Salt	Salt extraction includes conventional shaft mining for rock salt as well as brine, vacuum pan, open pan and solar production methods. Salt as a bi-product of desalination plants was included.

Table 9. Abiotic coastal resources

Biotic resource	Definition
Biodiversity	Biodiversity is a measure of variation at the genetic, species and ecosystem level. Biodiversity is not only linked to the equilibrium of ecosystems, but it is also a substantial source of potential new drugs, helps sustain a varied food chain and improves water quality, among many others.
Fisheries resources	Capture fisheries resources are highly diverse. FAO landing statistics refer to about 2,500 species or group of species most of which are finfish. By far the most numerous fish species, and those most important to fisheries, are teleosts or bony fish, which in the sea extend from small "grazing" species such as anchovy to large active predatory fish such as tuna.
Habitat condition and/or extent	Habitats (such as coral reefs, mangroves and seagrass) support biodiversity, which we rely on for food (such as fish), medicines (including painkillers and cancer drugs from marine species) and tourism (for instance, sport fishing and scuba diving).
Marine genetic resources	Biodiscovery depends on access to marine organisms, collectively termed marine genetic resources.
Primary production	In most marine ecosystems, the primary source of energy is sunlight that drives photosynthesis by phytoplankton, seaweeds algae and so forth, which in turn support the wider ecosystem and the biotic resources it contains.
Water quality	Water quality refers to the chemical, physical, biological and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose.

Table 10. Biotic coastal resources

Coastal resources			Sedimentation	Turbidity	Nitrogen	Phosphorus	Temperature	Salinity	Current	Dissolved oxygen	Persistent toxins	Plastic / debris	Invasive species	Cumulative stressor impact on each coastal resource
			Stressors											
			Natural								***Non-natural***			
Coastal resources	**Abiotic**	Salt		Medium				High	Medium		High	Low	Medium	**13**
		Aggregates	High						Medium					**5**
		Coastal minerals						No impact found						**0**
		Oil and gas	Medium	Medium			High		Medium					**9**
		Renewables	Medium		Medium		Medium	Medium	High		Medium	Low		**14**
	Biotic	Fisheries resources	High	High	High	High	High	High	High	High	High	Medium	High	**32**
		Primary production	Medium	High	High	High	Medium	Medium	Medium	Low	Medium	Low	Medium	**23**
		Habitat condition and/ or extent	High	High	High	High	High	Medium	Low	Medium	High	High	Medium	**28**
		Biodiversity	High	High	High	High	High	High	High	High	High	High	High	**33**
		Marine genetic resources	High				High	Medium		Medium			Medium	**12**
		Water quality	Medium	High	High	Medium				High	High	High	Medium	**21**
Cumulative impact of stressor / 33			**23**	**19**	**17**	**14**	**19**	**17**	**18**	**14**	**19**	**14**	**16**	

Key		
	Strength of impact	**Weight**
(red)	*High*	3
(yellow)	*Medium*	2
(green)	*Low*	1
(grey)	*No impact found*	0
(white)	*No studies found*	0

Table 11. The strength of influence of stressors on coastal resources.

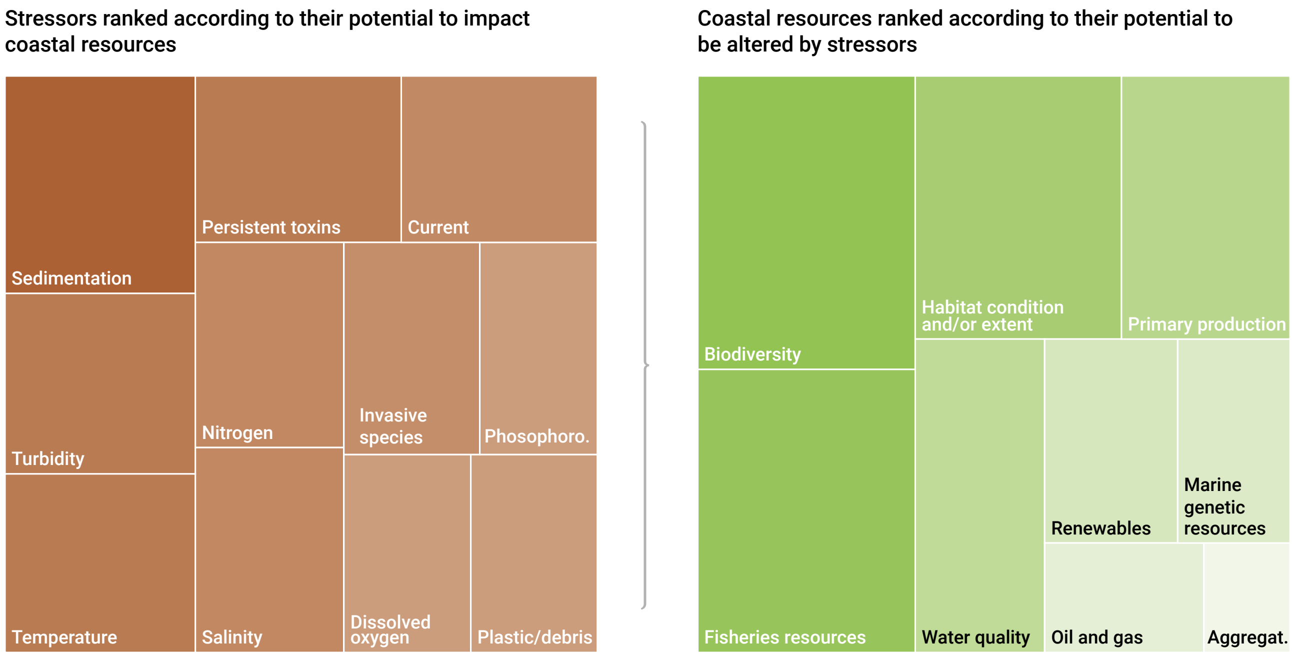
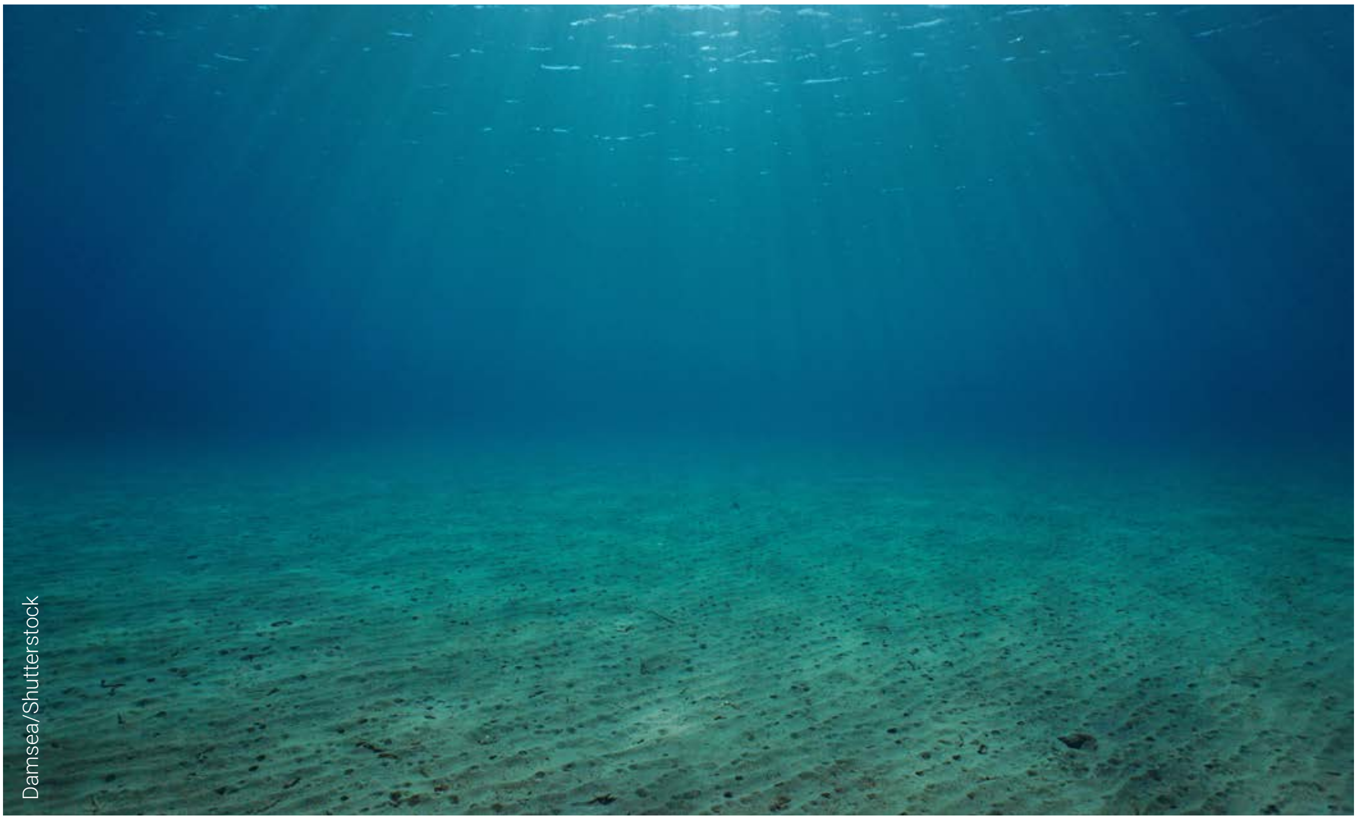


Table 12. Stressors ranked according to their potential to impact coastal resources

Stressors were found to have a substantially greater impact on biotic coastal resources than on abiotic ones. This is because biotic coastal resources are generally reliant upon, or are integral parts of, living coastal ecosystems that tend to be highly sensitive to disturbances and changes to natural conditions. There may also be tendencies in the literature to focus on more tangible and historically recognized stressors such as sedimentation and temperature, compared to relatively new stressors such as plastics (although this is changing), and to focus on impacts of stressors upon biotic rather than abiotic features. Sedimentation was found to be the stressor with the greatest impact across all coastal resources as, unlike most stressors, it was found to have negative impacts on both biotic and abiotic resources. The key biotic issue was the potential of sediment to smother living systems during resource extraction, with profound implications for the viability of productive ecosystems. Sedimentation was also found to introduce other material (often finer silts) into coarser coastal deposits (such as sand), thereby reducing the quality of the aggregate resource.

Several other natural stressors generated profound impacts on biotic coastal resources including turbidity, nitrogen, phosphorus, temperature and dissolved oxygen. These stressors are key variables for biotic coastal resources but have little known or expected influence on abiotic resources. For example, elevated phosphorus levels are unlikely to impact coastal aggregates in a meaningful way. This was compounded by a lack of studies on the impacts of stressors in general, but particularly the impact of biotic stressors on abiotic coastal resources. Plastics were more impactful on biotic than abiotic coastal resources, but despite great public interest, there remains a comparatively limited evidence base to consider its impact on abiotic coastal resources. The impacts of plastics on living resources were mainly the result of their toxic and physical effects when ingested. Microplastics have been shown to act as vehicles for contaminants and organic pollutants. A study by Silva-Cavalcanti *et al.* (2017), conducted on the Pajeu River in North-East Brazil, found that, on average, 83 per cent of the fish *Hoplosternum littorale,* had microplastics in their gut, with the highest proportion found on urbanized sections of the river. More broadly, it was clear that natural stressors have the greatest impact and that their impact is particularly focused on biotic coastal resources.

Biotic coastal resources were most impacted by coastal stressors because of their dependence on the condition of the coastal ecosystem. As such, biodiversity and fisheries resources were the coastal resources most impacted by stressors. Marine genetic resources are likely to be significantly impacted but there is a lack of available evidence. There is also a significant lack of



evidence concerning the effects of stressors on abiotic coastal resources, giving the impression that abiotic coastal resources are largely immune from stressors arising from land-based activities. Given the lack of evidence, the effects on abiotic coastal resources must be treated in a precautionary manner.

4.4 The impact of land-based activities on coastal resources

The next stage of the analysis was to combine the results of sections 4.2 and 4.3 in order to define the cumulative impact pathways between land-based activities and coastal resources. Each impact pathway was determined by combining the strength of impact between each land-based activity and stressor (the values in Table 7) and the strength of the impact between each stressor and coastal resource (the values in Table 11). This approach goes beyond simply assessing the impact of one activity upon one resource (as is common in previous studies) but considers the number and strength of impact pathways through which a land-based activity impacts a coastal resource to determine 'cumulative impact pathways'. Considering multiple impact pathways is important as it better reflects the reality that coastal resources are impacted by multiple land-based activities at any one time.

The overall impact pathway was determined numerically by multiplying the impact of each land-based activity on each stressor (rated 1-3) with the impact of each stressor on each coastal resource (rated 1-3). As the maximum impact of a land-based activity on a potential ecosystem stressor is 3, and the maximum impact of a potential ecosystem stressor on a resource is 3, and there are 11 potential stressors, the maximum cumulative impact of a single land-based activity on a resource is (3 x 3) x 11 = 99. This calculation is made for each cell in Table 13. The evidence quality ratings produced during the development of Tables 7 and 11 are used to calculate the quality of the body of evidence underpinning the relationships presented in Table 13. The approach used to produce the evidence scores was explained in chapter 2. However, in summary, for each cell in Table 13 the supporting evidence was rated according to its:

1. Average quality (scored between 1 and 3)
2. Average strength (scored between 1 and 4);
3. Size of the body of evidence (scored between 1 and 3).

These ratings were then combined into a percentage average of the maximum possible quality rating. The cumulative impact of land-based activities on coastal resources is presented in Figure 8, which was calculated by adding the impact of each land-based activity on each resource together. As there are 12 activities, and the impact of each activity was rated 0-99, the maximum cumulative impact is 1188 (12 x 99).

Land-based activities	Resources										
	Abiotic					Biotic					
	Salt	Aggregates	Coastal minerals	Oil and gas	Renewables	Fisheries	Primary production	Habitat condition and/or extent	Biodiversity	Marine genetic resources	Water quality
Agriculture	24	9	0	12	25	66	49	64	69	19	57
Forestry	17	13	0	16	23	50	40	46	51	11	40
Sewage discharge	22	6	0	10	19	63	47	61	66	16	59
Industrial plants and factories	24	10	0	12	25	57	39	52	60	20	43
Coastal infrastructure	23	13	0	16	25	57	40	51	60	22	43
Land reclamation	19	15	0	16	24	44	32	37	45	13	32
Port and harbour	35	15	0	18	31	76	54	64	78	25	55
Aquaculture	27	11	0	14	26	68	51	61	69	24	52
Salt extraction	21	7	0	8	24	39	27	32	39	15	20
Coastal aggregate mining	18	15	0	18	21	42	32	35	42	11	29
Other coastal mining	13	6	0	8	14	33	28	33	33	6	29
Tourism and recreation	20	9	0	8	17	42	30	42	45	15	38

Legend

Very strong quality of evidence
Strong quality of evidence
Medium strength quality of evidence
Low quality of evidence
30 Strength of impact between land-based activities and coastal resources from a (maximum of 99)

Table 13. Impact of land-based activities on coastal resources

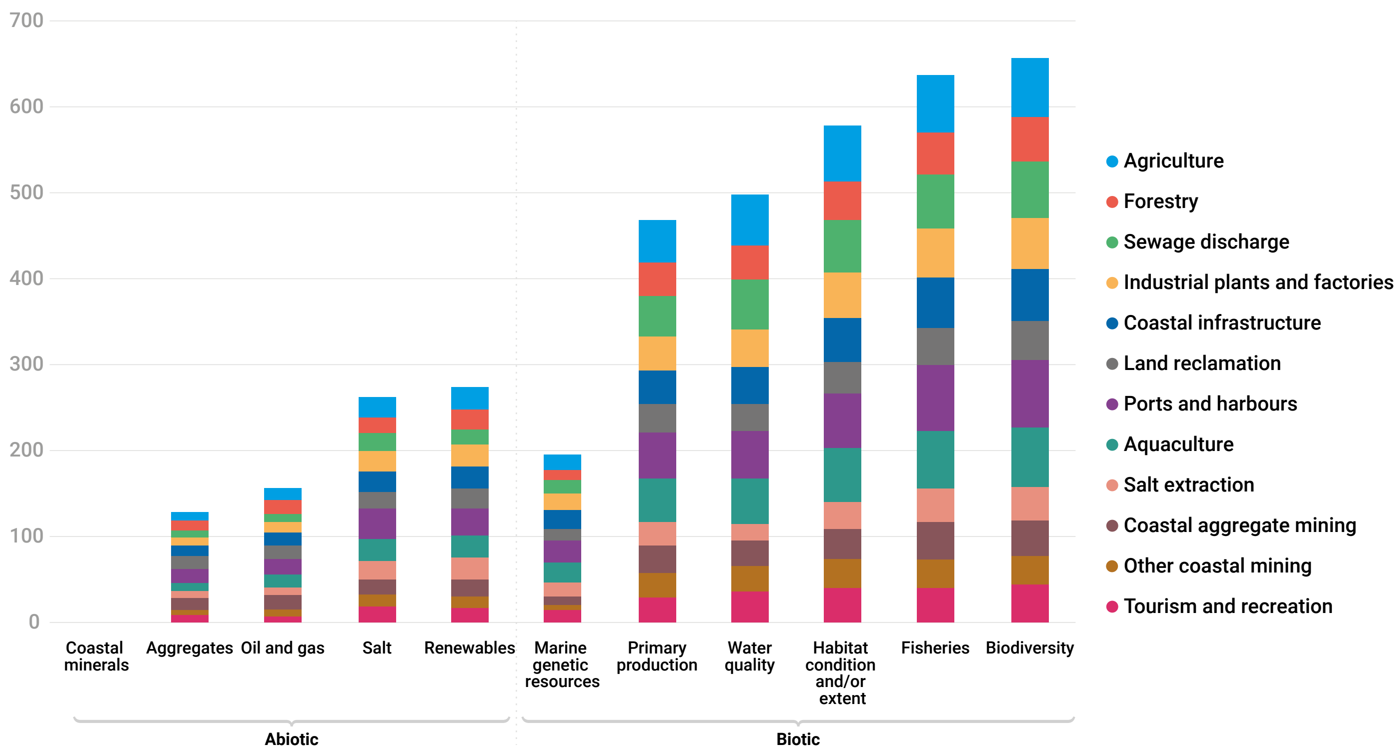


Figure 8. Cumulative influence of land-based activities on coastal resources

The results presented in Table 13 and Figure 8 combine the results from sections 4.2 and 4.3 to show the cumulative impact pathways linking land-based activities to the condition of coastal resources. It is clear that land-based activities generate multiple impacts of varying strength on coastal resources and that biotic coastal resources are more impacted by land-based activities than abiotic coastal resources. However, this is in part due to the comparative lack of studies focusing on abiotic resources.

Agriculture, ports and harbours and aquaculture are the land-based activities generating the greatest effects on coastal resources. These activities generate effects on both abiotic and biotic coastal resources, but are particularly impactful on biotic resources - with fisheries resources, primary production, habitat condition and biodiversity the most seriously affected coastal resources. This builds on the analysis presented in Table 8, which highlighted that ports and harbours, agriculture and aquaculture generated the most significant stressors across their life cycles. Land reclamation, salt extraction, coastal aggregate/other mining and tourism/recreation were the land-based activities that had the least impact on coastal resources, largely due to their limited impact on abiotic coastal resources and comparatively moderate impact on biotic coastal resources. It should also be noted that, in some cases, the classification of land-based activities may create a perceived under-representation of impact. For example, tourism and recreation generate significant sewerage and waste discharge, which is treated as separate land-based activity, thereby potentially underestimating the impact of tourism and recreation activities on coastal resources.

These headline results suggest that the management of coastal resources cannot be undertaken in isolation from land-based activities. They also suggest that governance priorities should be focused on agriculture, ports/harbours and aquaculture as the most impactful land-based activities. The results also demonstrate that sector-specific management is insufficient to manage coastal resources, as many of the land-based impacts originate from activities well outside of the coastal resource sector. For example, fisheries resources and biodiversity resources were affected, to some degree, by all land-based activities included in the study.

There is comparatively strong evidence that all biotic coastal resources are significantly impacted by land-based activities, as they are sensitive to changes in both natural and non-natural stressors. Biotic coastal resources were found to be particularly sensitive to agriculture, ports/harbours and aquaculture. This is partly because, unlike most other land-based activities, they generate both natural and non-natural stressors. Biodiversity was the coastal resource that suffered the greatest cumulative impact of land-based activities. It also bore the largest single land-based impact from ports and harbours, due to the multiple natural and non-natural stressors arising from that form of infrastructure. The results also suggest that any coastal resource governance framework must consider the multiple impact pathways arising from land-based activities, as any intervention focused on a single stressor or single activity will have limited influence on the condition of any given coastal resource.

There is little evidence that abiotic coastal resources are significantly impacted by land-based activities. For example, aggregates and coastal minerals were found to not to be notably impacted by land-based activities. Similarly, oil and gas resources were found to be relatively unaffected by land-based activities. Although in the case of oil and gas, the lack of impact could be partly due to their depth in the water column. In the case of all other abiotic resources it may be partially explained by a limited evidence base. The lack of evidence most likely stems from a combination of two non-exclusive factors: 1) a lack of studies exploring these relationships and 2) a 'real' lack of expected impact. As indicated in chapter 2, we attempted to separate these factors by adopting different assessments of impact strength and evidence quality. However, the analysis indicated that the lack of evidence undermined any assessment of impact. In management terms, this suggests that a precautionary approach should be taken, in which the absence of evidence should not be taken to mean the absence of a relationship between a land-based activity and coastal resources.

4.5 Limitations

The dynamic nature of coastal systems makes it difficult to generalize about the relationships between land-based activities and coastal resources, as we have done in this analysis. As such, it is important to recognize the following caveats, which may have significant local implications:

- The impact of any land-based activity (and associated stressors) on coastal resources, particularly biotic resources, can vary depending on the location, type, condition and resilience of the local ecosystems (with systems already impacted in some way being more vulnerable to additional pressures).
- The relationships between land-based activities and coastal resources are often interconnected and non-linear, whereby positive impacts can be undermined by other negative impacts, while other impacts may be minor until a tipping point is reached, when the system resets or substantively changes.
- There is limited evidence of the impact of certain stressors on abiotic coastal resources (including salt, aggregates, coastal minerals, oil and gas and marine renewables). This was in part due to the lack of available scientific literature examining these topics.
- Some stressors had a positive impact on primary production. For example, an increase in nitrogen generally increases primary production. However, extremely high primary production associated with algal blooms has a significant negative feedback loop on other ecosystem stressors (turbidity and dissolved oxygen). It should therefore be noted that primary productivity is not, in all circumstances, a beneficial coastal resource.
- In terms of biodiversity, the influence of stressors greatly depends on what species assemblages are considered. For example, some benthic invertebrates might benefit from greater sedimentation, whereas organisms and habitats relying on light availability will be negatively affected.
- The influence of a given stressor depends on the spatial scale considered. For example, while seawater temperature will define whether or not a coastal mineral crystallizes, these temperatures are usually extreme on a very local spatial scale. Therefore, small global changes in sea temperature are unlikely to affect mineral availability.
- Some of the relationships assessed in this study are very complex. For example, the influence of nitrogen and phosphorus on biotic coastal resources is often highly dependent on other environmental variables, nutrient ratios and the species and habitat considered.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5

IMPACT OF LAND-BASED ACTIVITIES ON THE BLUE ECONOMY

Unsplash/Chris Pagan

The aim of this chapter is to identify the impacts of land-based activities on selected blue economy sectors. This is undertaken by considering the reliance of each blue economy sector on the coastal resources included in this study, then assessing its level of vulnerability to change in the coastal resource base from land-based activities. Given the increasing focus on the transition to a sustainable blue economy in national and international ocean policy, it is important to consider the implications for the sustainable blue economy of changes to the coastal resource base. In terms of the DPSIR framework, this element of the study explores the impact of changes to the state of coastal resources.

For economic sectors operating in the sustainable blue economy, understanding their vulnerability to changes in coastal resources, along with the likelihood of those changes happening, is essential to their future plans. The sustainable blue economy sectors in this study are related to the resources outlined in section 4.4 (aquaculture; tourism and recreation; oil and gas; marine renewables; salt extraction) and other economically and socially valuable maritime industries (fishing, shipping, coastal aggregate, other coastal mining and submarine cabling). The analysis was undertaken in the following way:

- First, for each sustainable blue economy activity, its level of dependency on a given resource is scored according to three criteria:
    - Not dependent: The activity is not dependent on the availability of the coastal resource in any way. It is entirely independent of this resource and would not be affected by changes in its availability (attributed weight of 0).
    - Partially dependent: The activity is partially dependent on the availability of the coastal resource. Partial dependence was selected when a coastal resource could be replaced with an alternative coastal resource with no significant effect on the blue economy activity. Partial dependence can be at any stage of a blue economy's life cycle (attributed weight of 1).
    - Fully dependent: The activity is entirely dependent on the availability of a coastal resource. Fully dependent was only awarded to relationships in which the complete depletion of the resource or its complete modification in such a way that it is no longer fit for purpose, would result in the blue economy activity no longer being able to operate in an area (attributed weight of 2).

The dependency and vulnerability of each activity in terms of coastal resources (shown in Tables 14 and 15) were determined based on a combination of expert opinion and the literature collected throughout chapter 4. Where uncertainties remained, additional grey and peer-reviewed literature was consulted. A relative measure of vulnerability is presented in Figure 9.

- As the maximum impact upon a coastal resource from each land-based activity is 99, and there are 12 land-based activities, the maximum cumulative impact upon a coastal resource from land-based activities is 99 x 12 = 1188. Each dependency rank (0-2) was then multiplied by the cumulative impact of each land-based activity on each resource (section 4.4). The resulting score reflects the vulnerability of different industries to the depletion of a given resource, out of a maximum possible score of 2376 (1188 x 2).


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			Blue economy activity									
			Aquaculture	Fishing	Tourism	Shipping	Submarine cabling	Oil and gas	Marine renewables	Salt extraction	Coastal aggregate mining	Other coastal mining
Resources	Abiotic	Salt	1	1	1	1	0	1	1	2	1	1
		Aggregates	1	1	1	1	0	1	1	1	2	1
		Coastal minerals	1	1	1	1	1	1	1	1	1	2
		Oil and gas	1	1	1	1	1	2	1	1	1	1
		Marine renewables	1	0	1	0	0	1	2	1	1	1
	Biotic	Fisheries resources	1	2	1	1	0	0	0	0	0	0
		Primary production	1	1	1	0	0	1	0	0	0	0
		Habitat condition and/or extent	1	1	1	0	0	0	0	0	0	0
		Biodiversity	1	1	1	0	0	0	0	0	0	0
		Genetic	1	1	0	1	0	0	0	0	0	0
		Water quality	1	1	1	0	0	0	0	1	0	0

Dependency	Rank
Not dependent	0
Partially dependent	1
Fully dependent	2

Table 14. Dependency of blue economy activities on abiotic and biotic resources

			Blue economy activities									
			Aquaculture	Fishing	Tourism	Shipping	Submarine cabling	Oil and gas	Marine renewables	Salt extraction	Coastal aggregate mining	Other coastal mining
Coastal resources	Abiotic	Salt	263	263	263	263	0	263	263	526	263	263
		Aggregates	129	156	274	637	0	578	657	197	994	0
		Coastal minerals	0	0	0	0	0	0	0	0	0	0
		Oil and gas	156	156	156	156	156	312	156	156	156	156
		Marine renewables	274	0	274	0	0	274	548	274	274	274
	Biotic	Fisheries resources	673	1346	673	673	0	0	0	0	0	0
		Primary production	469	469	469	0	0	469	0	0	0	0
		Habitat condition and/or extent	578	578	578	0	0	0	0	0	0	0
		Biodiversity	657	657	657	0	0	0	0	0	0	0
		Bioprospecting	197	197	0	197	0	0	0	0	0	0
		Water quality	497	497	497	0	0	0	0	497	0	0
Total vulnerability of industry / 26,136			**3893**	**4319**	**3841**	**1926**	**156**	**1896**	**1624**	**1650**	**1687**	**693**

Table 15. Vulnerability of blue economy activities to changes in coastal resources resulting from land-based activities (rated 0-2376)

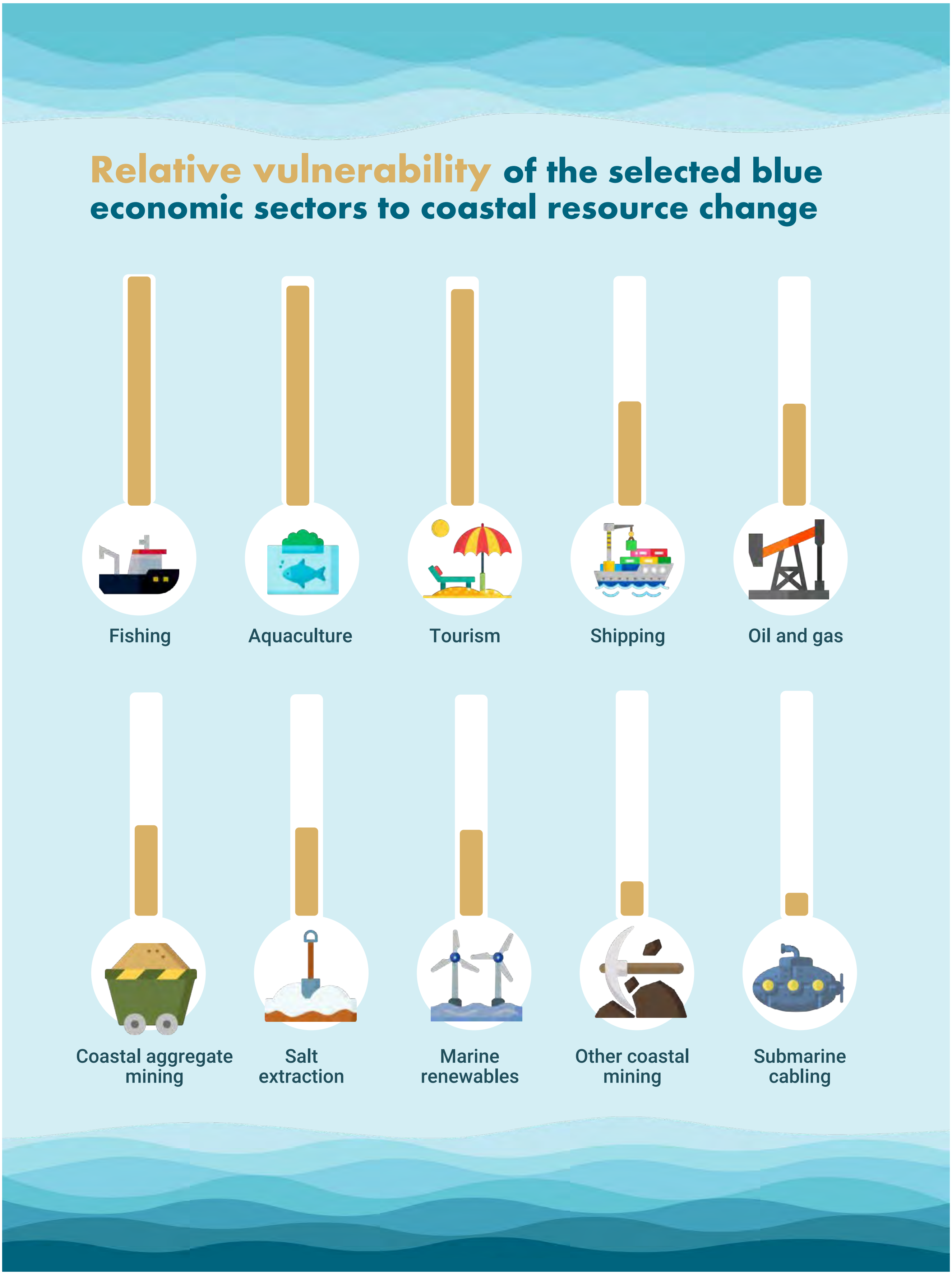

Figure 9. Relative vulnerability of selected blue economic sectors to changes in coastal resources arising from land-based activities. Vulnerability is relative to the most vulnerable activity (fishing).

Although the vulnerability of blue economy to resource change can range between 0 and 2376, an activity can only reach a score of 2376 if it is entirely dependent on a specific resource and that resource is impacted, to the maximum extent, by all possible impact pathways from land-based activities.

The results showed that aquaculture, fishing and tourism were significantly more vulnerable than other blue economy activities. Their greater vulnerability principally stems from their dependency on biotic resources that, as outlined in previous chapters, are often sensitive to multiple stressors arising from land-based activities. In contrast, blue economy activities reliant on abiotic resources were generally less vulnerable to land-based activities, due to the relatively limited number of pathways through which land-based activities can impact the coastal resources upon which they depend. It should, however, be noted that significantly more studies have been conducted exploring the impact of land-based human activities and stressors on biotic resources than abiotic.

Similarly, some of the assessed dependencies between coastal resources and blue economy sectors might appear confusing at first glance. For example, one might wonder how the shipping industry partially relies on the availability of salt, coastal minerals and aggregates. The reason for this scoring is that ship construction requires the use of aggregates (for concrete production), coastal minerals (for certain types of metals) and salt (to produce certain paints, aluminium and metals). Similarly, the fishing industry is reliant upon aggregates for construction materials. The basic construction materials required include cement and aggregates, making the fishing industry partially dependent on the availability of aggregates (Sciortino, 2010).


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6

THE EFFECTS OF EXTRACTIVE ACTIVITIES ON COASTAL RESOURCES


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6.1 Introduction

This chapter is a case study designed to test the method applied at the global scale to determine the impact of land-based extractive activities on coastal resources. Minerals and metals underpin national economies, provide crucial raw materials for industrial activities and are inputs to almost every sector of the global economy. As such, it is likely that extractive resources will continue to play a central role in driving the global economy despite efforts to decouple economies from resource use and towards greater recycling (IRP, 2020). This sector encompasses a broad range of activities that can occur in both the land and sea components of the coastal zone and it therefore has the twin characteristics of generating impacts on coastal resources and potentially being affected by changes in coastal resources. As such, examining the extractive industries allows important feedback loops to be identified and considered. The analysis presented in this chapter was discussed and validated at a workshop held in Beijing in January 2019. The chapter begins with an overview of resource extraction activities, particularly those commonly undertaken in coastal areas. Following the method used in chapter 4, this chapter presents an analysis of the stressors generated by extractive activities and the impact of those stressors on coastal resources.

6.2 Context

There are many different types of extractive industries, including aggregate mining and dredging; placer mining; salt mining; industrial and metallic minerals mining; and oil and gas extraction. The extraction of coastal minerals is a global activity, taking place on every continent except Antarctica. The expansion of cities is contributing to an increase in dredging and demand for marine aggregates. For example, the Palm Jumeirah and Palm Jebel Ali islands, the World archipelago and the Burj Khalifa tower in Dubai were all constructed with marine sand, most of which was imported from Australia (Peduzzi, 2014). Meanwhile, Singapore has been able to increase its land area by more than 22 per cent over the last 40 years using sand dredged from beaches in Indonesia, Malaysia, Thailand and Cambodia (Peduzzi, 2014). Increased demand for new technology is driving the mining of placer minerals such as titanium, zirconium, rutile, ilmenite, gold and tin. In addition, there is an established history of diamond mining in the coastal waters off the Skeleton Coast in Namibia, which involves the suction of sediment onto a marine vessel for processing.

The ecological impacts of extractive activities are extensive, destructive and often irreversible. Dredging, for example, has profound impacts on the fauna living in the seabed. An assessment of benthic fauna in the English Channel following sand dredging showed an 80 per cent reduction in species richness and a 90 per cent decrease in abundance and biomass (Desprez, 2000). Furthermore, the structure of the seabed changed from one dominated by coarse sands to one dominated by fine sands, which will have long-lasting implications for the local ecosystem (Desprez, 2000). Extraction and processing of minerals, sometimes significant distances inland, can leave a heavy footprint on the world's coasts in terms of metal contaminants - with elevated concentrations of zinc, chromium, nickel, lead, cadmium, arsenic, mercury and copper posing significant environmental risks (Hudson-Edwards *et al.*, 2011).

6.3 The impact of extractive activities on coastal resources

The extractive activities considered in this chapter are presented in Table 16. These were determined by reviewing relevant literature to identify the most widespread, economically valuable and impactful extractive activities.

The generic stressors generated by land-based activities identified in chapter 4 are equally applicable to extractive activities, with the exception of nitrogen and phosphorus release, which were combined into one stressor defined as 'dissolved nutrients' to reflect more accurately the less discriminating effect of extractive activities on concentrations of dissolved nutrients. Consequently, the final stressors considered were sedimentation, turbidity, dissolved nutrients, temperature, salinity, current, dissolved oxygen, persistent toxins, plastic/other debris and marine invasive species. As in chapter 4, in order to determine and quantify the linkages between extractive activities and stressors in a systematic manner, a matrix was developed showing how each stressor could be influenced by each extractive activity (Table 17). The matrix was constructed using the following approach:

Extractive activity	Definition
Aggregate	Aggregates are materials such as sand, gravel, shell, slag and broken stone that can be mixed with cement or bituminous material to produce concrete or mortar.
Placer	Accumulations of materials including titanium, zirconium, rutile, ilmenite, gold and tin concentrated in overburden, stream sediments or beach materials.
Evaporites	Include the extraction from seawater or marine sediments of chlorides and sulfates such as salt, potassium and magnesium chloride, anhydrite and gypsum.
Sulfide	Seafloor massive sulfide deposits are only occasionally present in coastal areas and the extraction of these deposits is only at the advanced planning stage at present.
Oil and gas	Includes the exploitation of marine coal, gas hydrates, natural petroleum oil and gas. This type of mining takes place at water depths of 0-4000m.
Other coastal mining	Land-based mining for industrial minerals and metal-bearing minerals.
Salt extraction	Conventional shaft mining for rock salt.

Table 16. The extractive activities considered

- For each of the 70 possible extractive activity-stressor relationships (each cell of the matrix), one hour was spent searching the literature using the Web of Science core collection and ordering the results by relevance. A total of 176 papers were reviewed (full details in Technical annex www.resourcepanel.org/reports/governing-coastal-resources). When relevant peer-reviewed literature was unavailable, grey literature and literature from industrial bodies, where available, was consulted.
- Based on the evidence obtained from the time-limited search, each extractive-stressor relationship was characterized according to the strength of the influence of the activity on the stressor (using the categorization high, medium, low, no impact found or no studies found) and the direction of the influence found (using the categorization increase; decrease; neutral; and not applicable).
- Finally, the overall strength of the evidence was determined according to its size, quality and consistency using the method outlined in chapter 2.
- To calculate an average influence of each extractive activity on each stressor, a weighting was attributed to each activity-stressor relationship using the simple system of 3 for high impact, 2 for medium impact, 1 for low impact and 0 for no impact found. As each extractive activity can influence 10 potential stressors, the maximum influence of a land-based activity is 30 (10 x 3).

Table 18 shows the cumulative influence of each extractive activity on stressors. It shows that oil and gas extraction had the greatest influence on stressors, heavily impacting three of the eleven potential stressors and having some form of relationship with all other potential stressors. Its significant influence on stressors arises from all stages and operations of oil and gas production, which, if poorly managed, can be accompanied by undesirable discharges of liquid, solid and gaseous waste. In addition, the physical infrastructure required for oil and gas extraction generates significant environmental impacts during construction, operation and decommissioning. An example is the possible introduction of invasive species. The movement of equipment and personnel between sites and the development large-scale infrastructure such as transboundary pipelines provide possible pathways for invasive species.

The mining of seafloor massive sulfide deposits, although rarely found in coastal areas and currently in advanced planning stages only, was found to have the second greatest potential impact - with the capability to heavily affect four stressors but with no evidenced impact upon three of the stressors (salinity, current and invasive species). Persistent toxins and sedimentation were the stressors with the greatest influence across the full suite of extractive activities, largely as a result of the chemical and physical changes that result from the disturbance they create. The impacts of placer diamond mining, which is conducted off the coast of

South-West Africa, have been widely studied by DeBeers Corporation and academic researchers (Sowman and Raemakers, 2018). In order to determine and quantify the impacts of extractive activities on coastal resources arising in a systematic manner, the results of the matrix developed in chapter 4 (Table 11) were used. This was possible as the stressors identified for extractive activities are the same as those included in Table 11. As such, the results from Table 11 can be carried forward for use in the analysis of how extractive activities affect coastal resources.

As in chapter 4, the effect of every extractive activity on each coastal resource was calculated by combining the relationship between extractive activities and the stressors they generate, with the impact of each stressor on each coastal activity. This approach not only assesses the impact of one activity upon one resource (as is common in other studies), but also considers the number and strength of pathways through which an activity affects a resource in a cumulative manner. Considering multiple effects at once is important as it gives a holistic overview that better reflects the reality of the situation: namely that coastal resources are affected by multiple activities at any one time.

For each cell in Table 19, the effect of an extractive activity on the corresponding resource is determined by numerically multiplying the extractive activity-stressor relationship value by the stressor-resource relationship value. As the maximum impact of an extractive activity on a potential ecosystem stressor is 3, and the maximum impact of a potential ecosystem stressor on a resource is 3, and there are 10 potential stressors, the maximum cumulative effect of a mining activity on a coastal resource is 3 x 3 x 10 = 90. Table 18 also shows the relevant evidence rating, derived from combining the quality, strength and size of the body of evidence.

		Potential stressors									
		Natural							Non-natural		
		Sedimentation	Turbidity	Dissolved nutrients	Temperatures	Salinity	Current	Dissolved oxygen	Persistent toxins	Plastics & other debris	Invasive species
Extractive activities	Aggregate	↑	↑	↑	*	*	*	↓	↑	↓	*
	Placer	↑	↓	↑	*	*	*	*	↓	↑	O
	Evaporites	O	↑	↑	O	↑	↑		O	O	*
	Oil and gas	↑	↑	↑	↑	*	↑		↑		↑
	Sulfide	↑	↑	↑	O	*	*	*	↑		*
	Salt extraction	↑	↑	↑	↑	O	O	O	↑		N/A
	Other coastal mining	↑	↑	↑	N/A	N/A	N/A	N/A	↑		N/A

Key			
Strength of impact			Direction of impact
(red)	*High*	↑	*Increase*
(yellow)	*Medium*	↓	*Decrease*
(green)	*Low*	O	*Neutral*
(grey)	*No impact/no studies found*	*	*No impact found*
		N/A	*No studies found*

Table 17. The influence of extractive activities on stressors

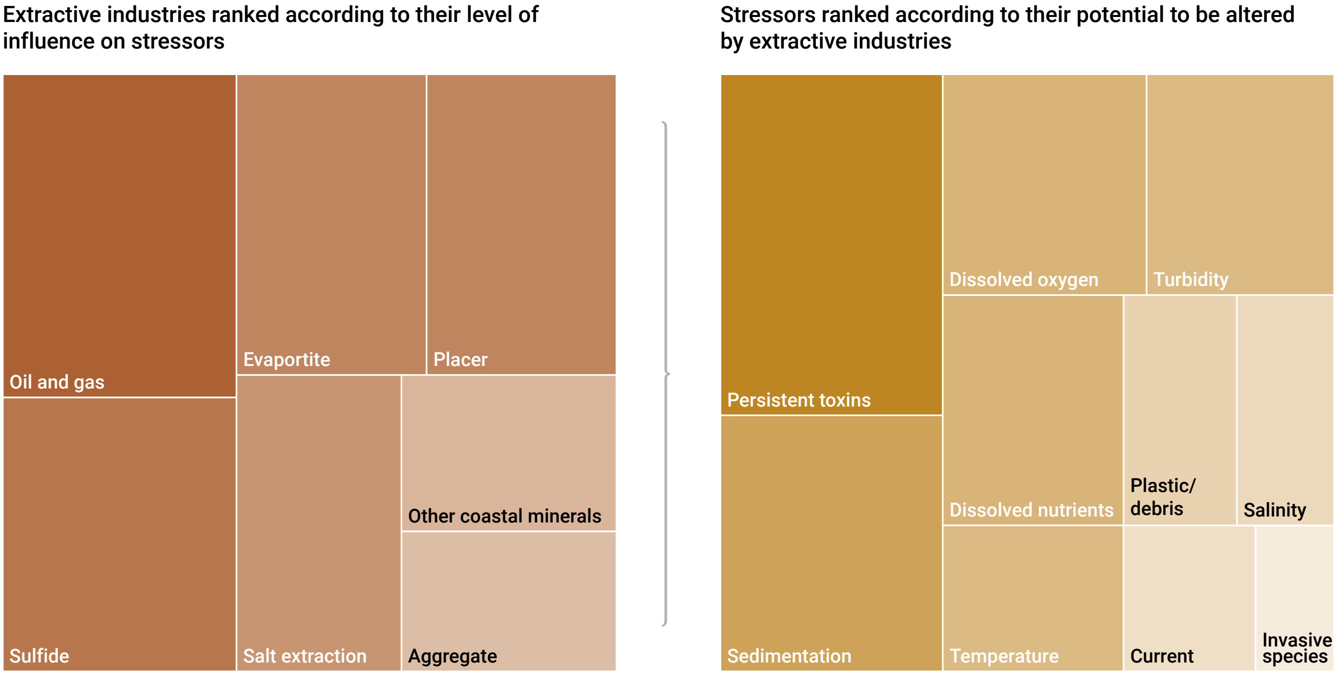

Table 18. Coastal mining activities ranked according to their cumulative influence on stressors

Mining activities	Resources										
	Abiotic					Biotic					
	Salt	Aggregates	Coastal minerals	Oil and gas	Renewables	Fisheries	Primary production	Habitat condition and/or extent	Biodiversity	Marine genetic resources	Water quality
Aggregate	6	9	0	6	12	24	15	22	24	13	21
Placer	18	9	0	10	21	42	32	44	45	11	41
Evaporites	26	5	0	10	19	45	30	37	45	18	29
Oil and gas	23	10	0	10	29	59	39	50	60	27	38
Sulfide	16	9	0	10	21	48	32	48	51	18	45
Salt extraction	21	7	0	14	24	39	27	32	39	15	20
Other coastal mining	13	6	0	8	14	27	27	27	27	6	25

Legend

Very strong quality of evidence
Strong quality of evidence
Medium strength quality of evidence
Low quality of evidence
30 Strength of impact between mining activities and coastal resources from a (maximum of 99)

Table 19. The impact of each extractive activity on marine resources and the supporting body

Table 19 shows there is strong evidence that biotic coastal resources are most impacted by extractive activities through both the chemical changes to coastal ecosystems (toxins and dissolved oxygen) and the physical problems created by sedimentation and plastic and other debris pollution. Marine genetic resources show relatively little impact, largely due to a limited evidence base. Similarly, the impact of extractive activities on abiotic coastal resources was limited, either due to a little 'real' impact or the lack of available evidence. Biodiversity was the resource most impacted by extractive activities due to its sensitivity to more stressors than other coastal resources.

6.4 The vulnerability of extractive activities to coastal resource change

An indicator of the vulnerability of extractive activities to changes in coastal resources was calculated by considering the dependency of extractive activities on each coastal resource and the impacts on that resource of changes arising from land-based activities. This gives an overall assessment of the vulnerability of extractive activities to a changing coastal resource base.
The dependency of each extractive activity on each coastal resource was measured using the method and criteria described in chapter 4 (not dependent; partially dependent; fully dependent). The levels of dependency (shown in Table 20) are based on expert opinion and the literature collected as part of the wider study. Where uncertainties remained, additional grey and peer-reviewed literature was consulted. Each dependency rank was then multiplied by the average impact of each extractive activity on each coastal resource to determine the vulnerability of extractive activities to coastal resource change. The vulnerability of extractive activities to the depletion of coastal resources was then calculated as follows:

- As the maximum effect upon coastal resources arising each extractive activity is 90 (see Table 19) and there are 7 extractive activities, the maximum cumulative effect upon a resource from all extractive activities is 90 x 7 = 630.
- As the maximum dependency of an extractive activity upon a coastal resource is 2 (fully dependent), and the maximum cumulative impact upon a resource is 630, the maximum vulnerability of a sector to change of a single resource is 630 x 2 = 1260.

The overall vulnerability of extractive activities to changes in coastal resources is shown in Table 21.

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			Extractive activities						
			Aggregate	Placer	Evaporites	Oil and gas	Sulfide	Salt extraction	Other coastal mining
Resources	Abiotic	Salt	0	0	1	0	0	2	1
		Aggregates	2	1	1	1	1	1	1
		Coastal minerals	1	1	1	1	2	1	2
		Oil and gas	1	0	0	2	0	0	1
		Marine renewables	1	1	1	1	1	1	1
	Biotic	Fisheries resources	0	0	0	0	0	0	0
		Primary production	0	0	0	0	0	0	0
		Habitat condition and/or extent	0	0	0	0	0	0	0
		Biodiversity	0	0	0	0	0	0	0
		Bioprospecting	0	0	0	0	0	0	0
		Water quality	0	0	1	0	0	1	0

Dependency	Rank
Not dependent	0
Partially dependent	1
Fully dependent	2

Table 20. The dependency of extractive activities on marine resources

			Extractive activities						
			Aggregate	Placer	Evaporites	Offshore oil and gas	Sulfide	Salt	Other coastal mining
Resources	Abiotic	Salt	0	0	123	0	0	246	123
		Aggregates	110	55	55	55	55	55	55
		Coastal minerals	0	0	0	0	0	0	0
		Oil and gas	55	0	0	110	0	0	55
		Marine renewables	140	140	140	140	140	140	140
	Biotic	Fisheries resources	0	0	0	0	0	0	0
		Primary production	0	0	0	0	0	0	0
		Habitat condition and/or extent	0	0	0	0	0	0	0
		Biodiversity	0	0	0	0	0	0	0
		Bioprospecting	0	0	0	0	0	0	0
		Water quality	0	0	219	0	0	219	0
Vulnerability of activity			**305**	**195**	**537**	**305**	**195**	**660**	**373**

Table 21. The vulnerability of extractive activities to changes in coastal resources (rated 0-1260).

Looking across the vulnerability to resource change of all extractive activities, salt and evaporite mining were found to be most vulnerable. This is because they are, to some extent, dependent on the purity and quality of sea water to produce high quality products, and water quality is impacted by an array of other activities. It is notable that many of the vulnerability scores shown in Table 21 are relatively low. This is a result of extractive activities being more dependent on abiotic than biotic resources. Abiotic resources have a lower average impact score, demonstrating that the vulnerability of extractive activities to land-based activities is relatively low, as these resources are less likely to be impacted by coastal change.

6.5 Governance of extractive activities

As shown in sections 6.3 and 6.4, land-based extractive activities mainly impact biotic coastal resources, yet mining itself is somewhat insulated from the effects of coastal resource change, with relatively minor exceptions pertaining to transport infrastructure for import of supplies and export of products. This asymmetric impact profile is potentially problematic from a governance perspective as there is little obvious 'self-interest' for the extractive sector to consider its impacts on coastal resources. The IRP (2020) has asserted that there is an urgent need to coordinate and reform the governance of the extractive sector due to its complex array of governance frameworks and initiatives operating at multiple scales. Key weaknesses include inadequate accounting and management of impacts on the natural environment and other resources and its limited linkages to other sectors (IRP, 2020). The following section considers the legal and voluntary arrangements, at various levels, for the governance of extractive activities with respect to their impacts on coastal resources and thereby potentially to the sustainable blue economy.

International laws and guidelines

At the global level, the United Nations Convention on the Law of the Sea (UNCLOS) is the key framework defining the use, preservation and conservation of marine resources. As set out by UNCLOS, coastal States have exclusive rights and jurisdiction over resources within their 200 nautical mile Exclusive Economic Zone. This includes marine aggregates such as sand and gravel, as well as offshore oil and gas deposits. In cases where the Exclusive Economic Zone extends into the deep sea (beyond the continental margin) nations may also have jurisdiction over resources such as polymetallic nodules, ferromanganese crusts or massive sulfide deposits (Cuyvers *et al.*, 2018). Aside from UNCLOS, multiple international frameworks support the sustainable use of resources including the Convention on Biological Diversity, UN Framework Convention on Climate Change and many of the Sustainable Development Goals (SDGs) set out in Agenda 2030. These frameworks set targets linked to the protection of ecosystems and the sustainable use of resources both on land and at sea, which by implication includes the negative impacts on coastal resources arising from land-based extractive activities. Extractive activities with a marine footprint are subject to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention), which seeks to protect the marine environment from human activities and has been in force since 1975.

Regional regulations

At the regional level, a number of guidelines focused on the management of seabed mining have been developed. In the European Union, the 'Minerals Policy Guide' (MIN Guide) initiative provides guidance for EU Member states on minerals policy and legislation, facilitates policy decisions related to mineral mining and aims to foster collaboration amongst stakeholders (Gottenhuber *et al.*, 2018). In the Pacific, a collaboration between the Pacific Community and the European Union provides a platform to bring together 15 Pacific Island countries to develop a regional legislative and regulatory framework to improve management of marine mineral resources and harmonize legislation throughout the region (Miller *et al.*, 2018). There are also a number of regional sea conventions that indirectly regulate mining and its impacts. Examples include the OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic, which includes regulations related to the dredging and dumping of sediments and mining waste materials, and the Helsinki Convention for the Protection of the Marine Environment of the Baltic Sea Area, which aims to prevent and eliminate pollution on the seafloor, coastal zones and drainage area of the Baltic Sea.

The European Marine Strategy Framework Directive (MSFD: 2008/56/EC) adopts a different approach by requiring Member States to take measures to maintain Good Environmental Status (GES) by 2020. GES is defined by several descriptors including descriptor 6 relating to sea-floor integrity, which is closely linked to marine aggregate extraction from the seabed. These legally binding regional arrangements may not focus on mining specifically, but their focus on protecting the marine environment from negative impacts and seeking to develop standards for the quality of the marine environment generate obligations that must be taken into account by extractive activities taking placed both on land and at sea. Terrestrial regional regulations that are focused on, or include, the impacts of land-based extractive activities on coastal resources are very limited and represent a clear gap in existing governance regimes in the extractive sector.

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National governance arrangements

Responsibility for governing extractive activities within the Exclusive Economic Zone lies with national authorities, which have the right to grant licenses and exploit resources as long as international commitments to marine protection are maintained (Cuyvers *et al.*, 2018). For instance, national governments are obliged to minimize "pollution from installations and devices used in exploration or exploitation of the natural resources of the seabed and subsoil" (UNCLOS, Article 194.3.c). States must also "protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threated or endangered species and other forms of marine life" (UNCLOS, Article 194.5), which is in line with commitments made through other international agreements such as the Convention on Biological Diversity. In most cases, national governments require an environmental impact assessment and/or a strategic environmental assessment to be conducted and approved before mining can start, to minimize the impact of extractive activities on the environment. As the impact on biodiversity is a key priority in most assessments (rather than the interests of other coastal resource or blue economy sectors), and biodiversity is particularly vulnerable to extractive activities, this may be seen a reasonable approach. It could also be argued that safeguarding biodiversity from the negative impacts of extractive activities is likely to protect other biotic resources. However, these approaches tend to focus on single-sector impacts rather than recognizing the cumulative impacts of a variety of land-based (and potentially sea-based) activities on biodiversity or other biotic coastal resources.

Governance of coastal extractive activities at the national level is dependent on the existence of adequate frameworks and effective enforcement. In some cases, legislation on coastal extractive activities is based on governance frameworks developed for the terrestrial environment. The effective enforcement of extractive sector regulations is an additional challenge for the governance of extractive activities. In most regions, aggregates such as sand are a common-pool resource extracted without regulation (Torres *et al.*, 2017). Even in areas where regulations on sand-mining exist, illegal extraction and trade continue - resulting in sand scarcity (which has sociopolitical, economic and environmental implications) (Torres *et al.*, 2017). In Bangka and Belitung, Indonesia, and Kirabati, for example, unregulated and illegal aggregate mining activities occur in parallel to regulated activities, and this has consequences for critical marine habitats as well as worker safety (Baker *et al.*, 2016).

Industry Initiatives and partnerships

Private sector actors are increasingly engaging in coastal and ocean governance issues and promoting sector-specific best practices (Campbell *et al.*, 2016). The private sector is also widely acknowledged as playing a key role in the achievement of international targets such as SDGs. By using industry codes of practice and management systems, companies engaging in extractive activities can improve their environmental and social performance. There are a large range of industry codes and partnerships aiming to promote best practice standards for specific extractive activities in coastal and terrestrial areas. The Extractive Industry Transparent Initiative, for example, is a global standard to promote open and accountable management of oil and gas and mineral resources, while the International Council of Mining and Metals (ICMM) promotes performance improvement in the metals and mining industry. The International Cyanide Management Code is a voluntary industry programme for gold and silver mining companies, which aims to improve the management of cyanide used in gold and silver mining, help protect human health and minimize environmental impacts. With respect to partnerships, the Proteus Partnership coordinated by UNEP-WCMC provides biodiversity data and advice to companies from the extractive sector to help them avoid negative impacts on biodiversity from their commercial activities, as well as providing an annual forum for members to meet and share practices related to biodiversity conservation. Similarly, the online Integrated Biodiversity Assessment Tool provides downloadable biodiversity data to the private sector, and other types of organizations, to enable informed decisions to be taken with respect to potential impacts on biodiversity.

Conclusion

In practice, there is considerable multi-scale variation in the legal and voluntary regulation of extractive activities and their effects on coastal resources. National governments, in particular, have had mixed success in mitigating the effects of extractive activities. This is compounded in some cases by their efforts being based on retrofitted legislation and variation in the level of protection offered by different countries. Given the transboundary nature of the impacts arising from extractive activities, it could be argued that bespoke regulations are required to reflect the specificities of coastal environments along with a coordinating mechanism to improve management across national and international jurisdictions (Thompson *et al.*, 2018). More fundamentally, as the demand for raw materials increases, it is becoming increasingly apparent that part of the solution for managing the environmental impacts of resource extraction lies in moving towards an alternative paradigm of production and consumption. Achieving a transition towards a circular economy will improve reuse and recycling rates, extend product lifespans and help to discourage overconsumption, thereby helping to address the root causes of human-induced impacts on coastal and marine environments (Thompson *et al.*, 2018; IRP, 2020).

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7

THE EFFECTS OF SHRIMP AQUACULTURE ON COASTAL RESOURCES


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7.1 Introduction

This chapter is a case study designed to test the method applied at the global scale to determine the impact of land-based activities on coastal resources (in terms of the specific activity of shrimp aquaculture). Aquaculture refers to the breeding, rearing and harvesting of animals and plants in all types of water environments. Aquaculture has become the fastest growing food-producing sector, and is an increasingly important contributor to national economic development and food security. Globally, it supplies more than 50 per cent of all seafood produced for human consumption and is an important source of protein, essential fatty acids and - particularly in developing counties - income and employment. Aquaculture consists of a broad spectrum of users, systems, practices and species, operating through a continuum ranging from backyard household ponds to large-scale industrial systems. It is therefore difficult to draw conclusions about aquaculture as a whole from the analysis of shrimp aquaculture presented in this chapter. It should also be noted that aquaculture practices are changing rapidly, including the introduction of Recirculating Aquaculture Systems in Europe (which have a lower environmental impact).

Shrimp aquaculture can occur in both the land and sea components of the coastal zone and therefore has the twin characteristics of generating impacts on coastal resources and potentially being affected by changes in coastal resources. As such, examining aquaculture allows feedback loops in the analysis to be identified and considered. The analysis presented in this chapter was discussed and validated at a workshop held in Beijing in January 2019. The chapter begins with a broad overview of aquaculture activities. Then, following the method used in chapter 4, the chapter presents an analysis of the stressors generated by shrimp aquaculture activities and the impact of those stressors on coastal resources.

7.2 Context

Aquaculture has grown dramatically over the past 65 years, as shown in Figure 10. Aquaculture production is dominated by Asia (predominately China), which has accounted for 89 per cent of world aquaculture production for over 20 years (FAO, 2018). This is followed by the Americas (4.2 per cent), Europe (3.7 per cent), Africa (2.5 per cent) and Oceania (which contributes 0.3 per cent of world aquaculture production) (FAO, 2018). There is extensive evidence documenting aquaculture's environmental and ecological impacts, including land-use change and modification to make way for aquaculture facilities; the release of nutrients and organic materials into the environment through operational activities; the accidental release of stock - resulting in the potential spread of invasive species and disease; and the use of chemicals for disease treatment that may be toxic to other coastal species (Ribeiro *et al.*, 2014; Ottinger *et al.*, 2016). The potential impacts of these activities are substantial and often affect areas well beyond an aquaculture site, altering terrestrial, coastal and marine food webs and impacting species of plants, birds and mammals.

While ecosystems are naturally resilient and can absorb, adapt and recycle a range of inputs, this resilience is undermined by cumulative impacts that potentially result in significant and irreversible damage (Frankic and Hershner, 2003). Furthermore, there are concerns about how aquaculture affects other coastal activities such as fisheries and tourism. The growing global human population and rising consumption (chapter 2) mean that the global demand for food will increase, and aquaculture is likely to play a vital role in meeting that demand. In this context, it is a significant challenge to decouple the projected growth and intensification of aquaculture from the myriad of potential environmental and ecological impacts.

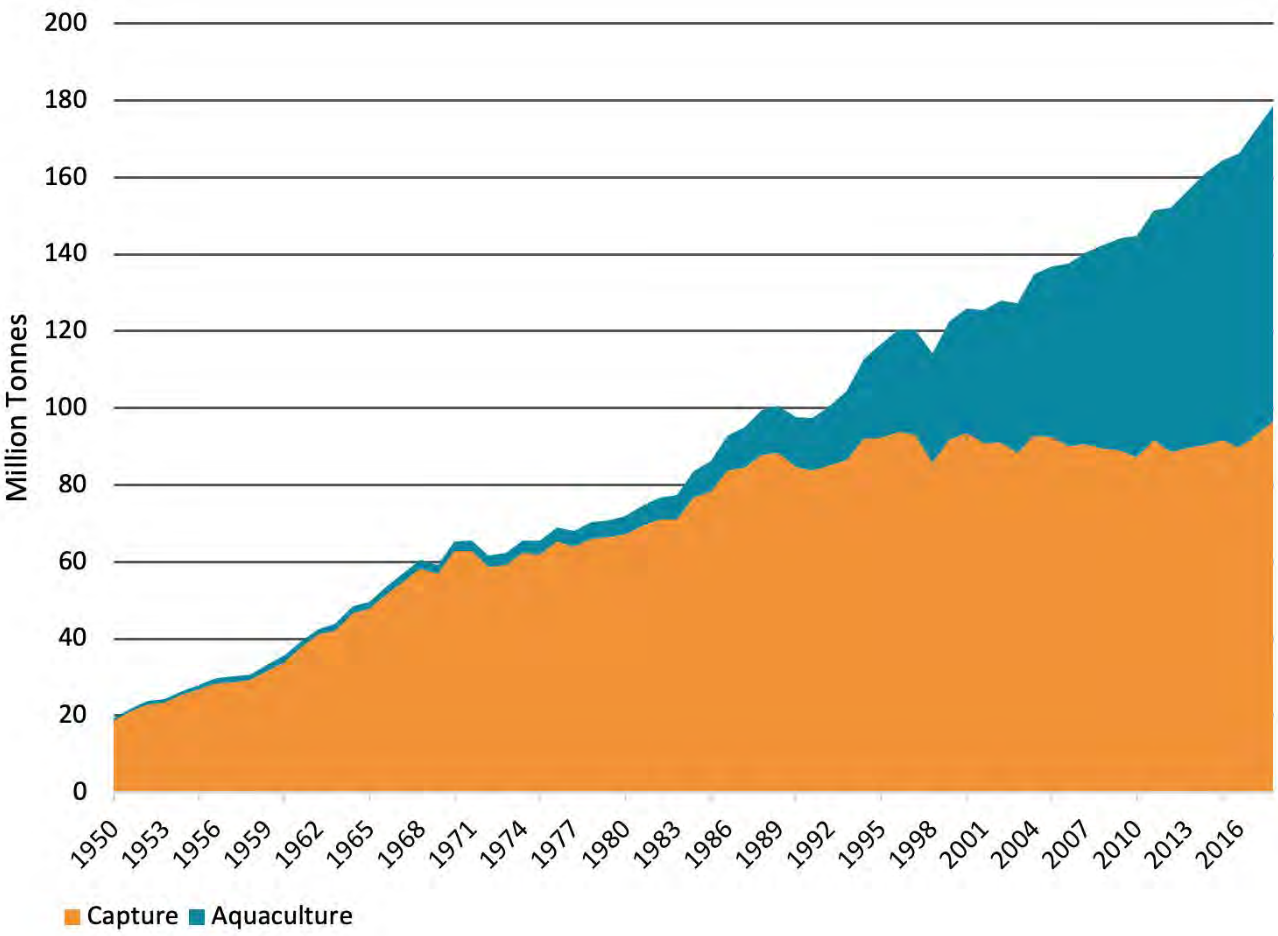

Figure 10. World capture fisheries and aquaculture production (FAO, 2020)

Aquaculture has played an increasing role in social and economic development in developing and developed countries in recent years. In industrial nations, aquaculture is known to bring jobs and infrastructure, particularly to isolated rural areas. However, aquaculture industries in developed nations suffer from low availability of high-paying jobs combined with a lack of appropriately trained staff willing to work in low-skilled and low-paid positions. Nonetheless, job retention in isolated areas helps stabilize community structure and drives secondary industry and services (Neiland *et al*., 1991). Aquaculture can cause unwanted societal effects when it produces boom and bust cycles, with potential collapses caused by disease outbreaks, food safety recalls or natural disasters. Aquaculture can prompt resource conflicts when traditional users feel that aquaculture is encroaching on their 'patch'. However, most of these disturbances to traditional societies are typical for fast-expanding industries, and are not specific to aquaculture alone (Orchard *et al*., 2015).

7.3 The impact of shrimp aquaculture on coastal resources

This chapter focuses on shrimp aquaculture due to its widespread global production, economic importance and documented environmental impacts. Shrimp aquaculture has grown significantly in most tropical and subtropical coastal areas of the world including Asia, Africa and the Americas (Kobayashi *et al*., 2015). Shrimp aquaculture is commonly undertaken in coastal ecosystems such as wetlands and estuaries, and often in close proximity to mangroves. In many cases, shrimp aquaculture genuinely straddles the land-sea interface. The stage of development, species and location all influence the stressors generated by shrimp aquaculture (see below):

Stage of development

After approximately one week as larvae, shrimp metamorphose into postlarvae. In the wild, postlarvae migrate into estuaries, which are rich in nutrients and low in salinity. When they mature, they migrate back into open waters as adults. In a shrimp-farming context, this life cycle occurs under controlled conditions to allow more intensive farming, reduce predation and accelerate growth and maturation:

- Larvae production: Until the mid-1980s, most farms were stocked with postlarvae, typically caught locally. However, to counteract the depletion of fishing grounds and to ensure a steady supply of young shrimp, the industry started breeding shrimp larvae in hatcheries. Large shrimp farms maintain their own hatcheries and tend to sell larvae to smaller farms in their local region, while small-scale hatcheries are very common throughout South-East Asia. Often run as family businesses and using a low-tech approach, they use small tanks (less than ten tons) and often low animal densities. The survival rate is anywhere between zero per cent and 90 per cent, depending on a wide range of factors including disease, weather and the experience of the operator. The larvae culture is usually carried out in recirculating systems with little impact on local or nearby areas using diverse technologies that allow good control of variables with low risk of released animals, pathogens, parasites and contaminated waters to the surrounding water bodies.
- Postlarvae production: Postlarvae are stocked in controlled nursery ponds. Many farms have tidal nursery ponds with constant water exchange with the sea in order to avoid the use of pumps, and in certain cases shrimp are cultured in cages in the sea. Many farms have nurseries where the postlarval shrimp are grown into juveniles for another three weeks in separate ponds or tanks, or so-called ‘raceways’. A typical nursery contains 150 to 200 animals per square metre. They are fed a high-protein diet for a maximum of three weeks before they are moved to the grow-out ponds. Nurseries have a higher environmental impact due to the space and volume of water they require.
- Adults: After postlarvae reach the required size, they are transferred to grow in ‘out ponds’ where they remain until they reach a marketable size (between three and six months). Shrimp are harvested using nets or by draining the ponds. Extensive shrimp farms using traditional low-density and low-tech methods are invariably located in coastal areas and are often close to mangroves, while intensive shrimp farms use engineered and constructed ponds.

Species

Shrimp aquaculture production has focused on a relatively small number of shrimp species due to their proven economic profitability and technical reliability. The most economically important species are the whiteleg shrimp (Littopenaeus vannamei) (also known as Pacific white shrimp or king prawn), tiger shrimp (Penaeus monodon) and Chinese shrimp (Fenneropenaeus chinensis). These species were the focus of our analysis.

Location

Shrimp aquaculture has extended to most tropical and subtropical areas of the world. Due to differences in regulation, aquaculture practices and species, the levels of environmental impact vary substantially. The locations selected for this analysis are Asia, Africa and Americas, as they best represent the diversity of countries producing farmed shrimp. The differences between the locations is as follows:

- Americas: Shrimp farming in Latin America and the Caribbean is a complex, diverse and dynamic activity, occurring in 22 out of 36 countries. Whiteleg shrimp constitutes 91 per cent of all shrimp farmed in the Americas, while five nations, led by Brazil, comprise 82 per cent of farmed production. The shrimp-farming industry has been linked to multiple environmental concerns, including mangrove deforestation, changed watercourses , pollution from organic feeds, chemical leaching, transfer of exotic species and diseases from one continent to another and the spread of diseases to wild species. There is a lack of trained staff, and national authorities have limited resources to deal with the sudden growth of the industry (leading to weak surveillance and enforcement).
- Asia: Generally speaking, shrimp farming in Asia is comparable to that in the Americas. Prior to 2000, the tiger shrimp (Penaeus monodon) was the most commonly reared species as it is within the species’ natural range and generates significant demand from both local and international markets. However, in recent years, the whiteleg shrimp has been preferred due to its resistance to white spot disease. The Asian shrimp aquaculture industry is widely operated by private entrepreneurs with enough capital to build intensive systems to raise

and produce higher yields. In recent years, whiteleg shrimp was introduced and contributed to a high percentage of shrimp production in Asia.

- Africa: Africa holds tremendous potential for the development of commercially viable shrimp aquaculture. To date, however, the perceived advantages of working in Asia and the Americas have meant relatively little investment in shrimp aquaculture in Africa. Nevertheless, investments are increasing in Madagascar and Egypt (Sadek *et al.*, 2011). The development of aquaculture in this region needs more study and investment, as well as planning and policy support.

Given the different developmental stages, species and locations involved in the assessment of shrimp aquaculture, the stressors used in chapter 4 were re-considered to ensure their relevance. As per the extractive activities case study, nitrogen and phosphorus concentrations were combined into one stressor, referred to as 'dissolved nutrients'. The stressors of turbidity, temperature, salinity and current were omitted due to their limited relevance to aquaculture and were replaced by organic particles, parasites and disease, genetic contamination and the reduction of natural populations (linked to the reliance of aquaculture on wild populations), which were considered to be more relevant (Wasielesky *et al.*, 2006; Lightner, 2007). As in chapter 4, in order to determine and quantify the linkages between aquaculture activities and stressors in a systematic manner, a matrix was developed showing how each stressor could be influenced by each aquaculture activity (Table 22). The matrix was constructed using the following approach:

- For each of the 90 possible aquaculture-stressor relationships (each cell of the matrix), an expert-judgement based assessment was made of the strength of the influence of the aquaculture activity on the stressor (using the categorization high, medium, low, no impact found or unknown) and the direction of the influence found (using the categorization increase; decrease; neutral; and not applicable). When expert judgement was unavailable, academic papers, relevant literature, grey literature and literature from industrial bodies was consulted. A total of 41 papers were reviewed. It should be noted that the use of expert judgement in the stressor analysis represented a variation from the methods used for the 'global' and extractive activity analyses. However, this was a useful test of an alternative application of the method to reflect contexts where there is little published evidence or there is a need for a rapid assessment of stressors and impacts.
- To calculate an average influence of each aquaculture activity on each stressor, a weighting was attributed to each activity-stressor relationship using the simple system of 3 for high impact, 2 for medium impact, 1 for low impact and 0 for no impact found. As each aquaculture activity can influence 10 potential stressors, the maximum influence of each aquaculture activity is 30 (10 x 3).
  The resultant ranking is presented in Table 23.

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		Potential stressors									
		Natural					*Non-natural*				
		Sedimentation	Organic particles	Dissolved nutrients	Dissolved oxygen	Reduction of natural populations	Persistent toxins	Plastics & other debris	Invasive species	Genetic contamination	Parasites and disease
Stage	Larvae	O	O	O	O	↑	↑	O	↑	↑	↑
	Postlarvae	O	O	↑	↓	↑	O	O	↑	O	O
	Adults	↑	↑	↑	↓	O	O	O	↑	O	O
Species	Pacific white shrimp	↑	↑	↑	↓	O	↑	O	↑	↑	↑
	Asian tiger shrimp	↑	↑	↑	↓	O	↑	↑	↑	↑	↑
	Chinese white shrimp	↑	↑	↑	↓	O	↑	↑	NA	↑	↑
Location	Americas	↑	↑	↑	↓	O	↑	↑	↑	↑	↑
	Asia	↑	↑	↑	↓	O	↑	↑	↑	↑	↑
	Africa	O	O	O	O	NA	NA	NA	NA	NA	O

Key			
Strength of impact			**Direction of impact**
	High	↑	*Increase*
	Medium	↓	*Decrease*
	Low	O	*Neutral*
	No studies found	*	*No impact found*
		N/A	*No studies found*

Table 22. Stressors generated by shrimp aquaculture

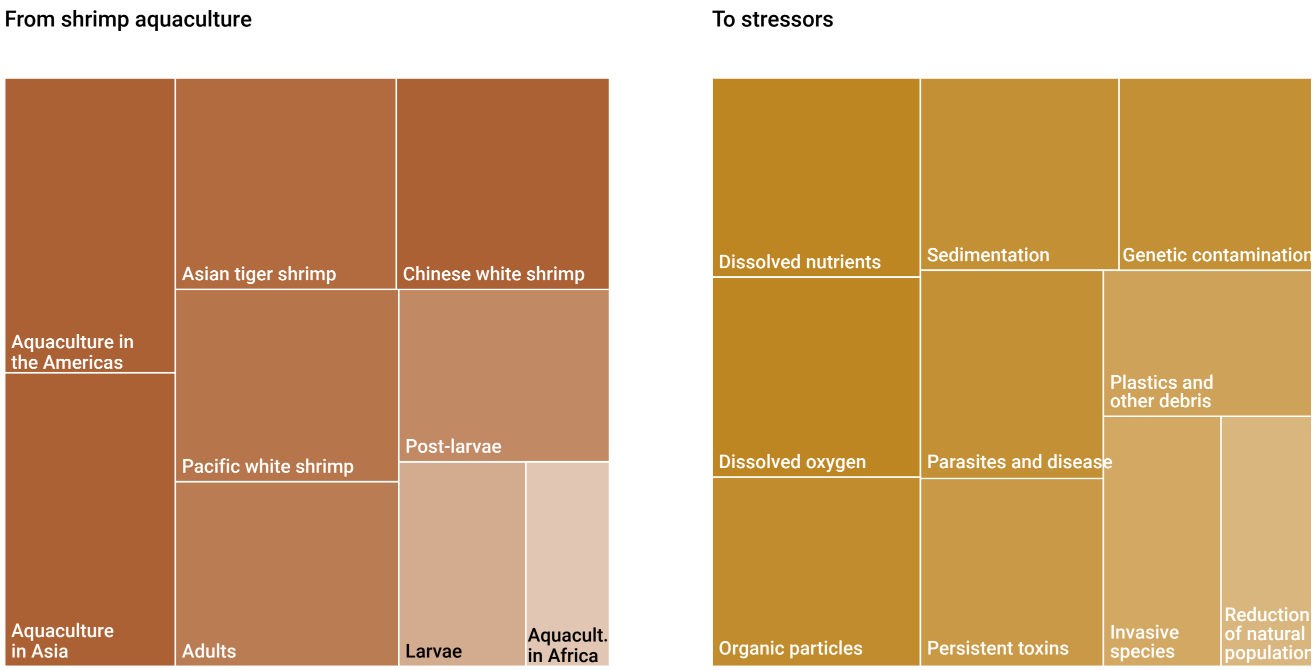

Table 23. Shrimp aquaculture activities ranked according to their cumulative influence on stressors

Overall, adult stage shrimp aquaculture (regardless of species) was found to generate nearly all stressors, both natural and non-natural, to a moderate or high level. This suggests that shrimp aquaculture is likely to have a significant effect on coastal resources, particularly biotic. Bangladesh is the world's fifth largest shrimp producer, and severe degradation of the coastal environment has occurred there. Of particular concern is the removal of mangroves due to unplanned and unregulated shrimp farm development. This has harmed biodiversity in coastal areas and led to saltwater incursion with an associated soil salinity increase of up to 500 per cent, endangering the viability of land-based agriculture in the coastal zone (Sohel & Ullah, 2012).

Although shrimp production in Africa was found to have the lowest stressor impact, this may be due to the limited amount of evidence available for this region rather than a lack of exposure to stressors. Stressor impact appears to increase from larvae to postlarvae and adult life stages, perhaps reflecting increased inputs to the aquaculture system as individuals mature. Dissolved oxygen and dissolved nutrient levels (both well documented consequences of aquaculture) were the stressors found to be most commonly generated, while a reduction of natural populations was found to be the least generated stressor. Shrimp aquaculture was found to increase plastics in coastal waters, although this was not related to life stage.

In order to determine and quantify the impacts on coastal resources arising from shrimp aquaculture stressors in a systematic manner, a matrix was developed mapping their connections. As some of the stressors were the same as those used in chapter 4, these results were carried forward. However, due to the inclusion of several additional stressors, a new assessment was conducted for the additional stressors, again using expert opinion. The resulting matrix is presented in Table 24, which shows that sedimentation had the highest impact of all stressors, closely followed by organic particles and persistent toxins. Natural stressors generated the greatest impact on coastal resources, and biotic resources were found to be the most sensitive to all stressors. As in the preceding analyses, abiotic coastal resources suffered little impact from aquaculture stressors. While these findings broadly align with expectations, there may also be a bias in the literature towards more tangible and historically recognized stressors such as sedimentation and temperature compared to relatively new stressors such as plastics, and also a bias towards studying the impacts of stressors upon species and ecosystems rather than other activities, such as salt production or marine renewables.

Resources			Natural: Sedimentation	Natural: Organic particles	Natural: Dissolved nutrients (N/P)	Non-natural: Dissolved oxygen	Non-natural: Reduction of natural populations	Non-natural: Persistent toxins	Non-natural: Plastic & other debris	Non-natural: Invasive species	Non-natural: Genetic contamination	Non-natural: Parasites and disease	Cumulative impact on resource / 33
Resources	Abiotic	Salt		Medium				High	Low	Medium			8
		Aggregates	High										3
		Coastal minerals											0
		Oil and gas	Medium	Medium									4
		Renewables	Medium		Medium			Medium	Low				7
	Biotic	Fisheries resources	High	High	High	High	High	High	Medium	High	High	High	26
		Primary production	Medium	High	High	Low	Low	Medium	Low	Medium	Low	Medium	18
		Habitat condition / extent	High	High	High	Medium	Medium	High	High	Medium	Medium	Medium	25
		Biodiversity	High	High	High	High	High	High	High	High	High	High	30
		Marine genetic resources	High			Medium	High			Medium	High	Medium	15
		Water quality	Medium	High	High	High		High	High	Medium		Low	20
Cumulative weight of stressor / 33			23	19	17	14	13	19	14	16	12	13	

Key		
Strength of impact		Allocated weight
(red)	*High*	3
(yellow)	*Medium*	2
(green)	*Low*	1
(grey)	*No impact*	0
(white)	*No studies*	0

Table 24. Effect of shrimp aquaculture stressors on coastal resources

As in chapter 4, the strength of each impact pathway between a shrimp aquaculture activity and a coastal resource was calculated by combining the relationship between aquaculture activities and the stressors they generate, with the impact of each stressor on each coastal activity. Therefore, for each cell in Table 25, the impact of each aquaculture activity on a corresponding resource is determined by numerically multiplying the aquaculture activity-stressor relationship value with the stressor-resource relationship value. As the maximum impact of an aquaculture activity on a potential ecosystem stressor is 3, and the maximum impact of a potential ecosystem stressor on a resource is 3, and there are 10 potential stressors, the maximum cumulative impact of an aquaculture activity on a coastal resource is 3 x 3 x 10 = 90. Table 25 does not show an evidence rating, as the evidence underpinning this analysis was primarily derived from expert opinion.

The analysis presented in Table 25 suggests that the location of a shrimp aquaculture facility does not have a particularly strong influence on the impact of aquaculture on coastal resources. However, all species at postlarval stage generate significant impacts on coastal resources (and biotic resources in particular). Biodiversity, fisheries and habitat are the biotic coastal resources particularly impacted by shrimp aquaculture. This is a direct result of the reliance of these resources on the quality of the coastal ecosystem, which is severely affected by the profound physical and chemical changes generated by shrimp aquaculture. Abiotic resources are comparatively unaffected by shrimp aquaculture, with the limited exceptions of salt production and renewable energy production. Salt relies upon clean water, which is compromised by aquaculture, while renewable energy is negatively impacted by sediment-laden water. It is clear from the analysis that shrimp aquaculture is a highly impactful activity that requires careful management to limit its effects on coastal resources.

Shrimp aquaculture activities	**Resources**										
	Abiotic					Biotic					
	Salt	**Aggregates**	**Coastal minerals**	**Oil and gas**	**Renewables**	**Fisheries**	**Primary production**	**Habitat condition and/or extent**	**Biodiversity**	**Marine genetic resources**	**Water quality**
Larvae	6	9	0	6	12	24	15	22	24	13	21
Post-larvae	18	9	0	10	21	42	32	44	45	11	41
Adults	26	5	0	10	19	45	30	37	45	18	29
Pacific white shrimp	23	10	0	10	29	59	39	50	60	27	38
Asian tiger shrimp	16	9	0	10	21	48	32	48	51	18	45
Chinese white shrimp	21	7	0	14	24	39	27	32	39	15	20
Americas	13	6	0	8	14	27	27	27	27	6	25
Asia	13	6	0	8	14	27	27	27	27	6	25
Africa	13	6	0	8	14	27	27	27	27	6	25

Legend

30 Strength of impact between aquaculture activities and coastal resources from a (maximum of 90)

Table 25. Impact of shrimp aquaculture activities on coastal resources

7.4 The vulnerability of shrimp aquaculture to coastal resource change

An indicator of the vulnerability of shrimp aquaculture to changes in coastal resources was calculated by considering the dependency of shrimp aquaculture on each coastal resource and the impacts on that resource in the face of changes caused by land-based activities. This gives an overall assessment of the vulnerability of shrimp aquaculture to a changing coastal resource base. The dependency of each shrimp aquaculture activity on each coastal resource was measured using the method and criteria described in chapter 4 (not dependent; partially dependent; fully dependent). The levels of dependency (shown in Table 26) are based on expert opinion and the literature collected as part of the wider study. Where uncertainties remained, additional grey and peer-reviewed literature was consulted. Each dependency rank was then multiplied by the average impact of each shrimp aquaculture activity on each coastal resource to determine the vulnerability of aquaculture activities to coastal resource change.

The vulnerability of shrimp aquaculture activities to the depletion of coastal resources was then calculated as follows:

- As the maximum impact upon coastal resources arising from each shrimp aquaculture activity is 90 and there are three shrimp aquaculture activities to consider (stage, species and location), the maximum cumulative impact upon a resource from an aquaculture activity is 90 x 3 = 270.
- As the maximum dependency of a shrimp aquaculture activity upon a resource is 2 (fully dependent) and the maximum cumulative impact (per activity) upon a resource is 270, the maximum vulnerability of an activity to a single resource is 270 x 2 = 540.

The overall vulnerability of shrimp aquaculture activities to changes in coastal resources is shown in Table 27.

			Shrimp aquaculture activity								
			Larvae	Post larvae	Adults	Pacific white shrimp	Asian tiger shrimp	Chinese white shrimp	Americas	Asia	Africa
Resources	Abiotic	Salt	1	2	2	1	2	2	1	1	1
		Aggregates	0	0	0	0	0	0	0	0	0
		Coastal minerals	0	0	0	0	0	0	0	0	0
		Oil and gas	0	0	0	0	0	0	0	0	0
		Marine renewables	0	0	0	0	0	0	0	0	0
	Biotic	Fisheries resources	0	1	1	2	2	2	2	2	2
		Primary production	2	2	2	2	2	2	2	2	2
		Habitat condition / extent	0	2	2	2	2	2	2	1	2
		Biodiversity	1	2	2	2	2	2	2	2	2
		Bioprospecting	0	0	0	1	0	0	1	0	0
		Water quality	2	2	2	2	2	2	2	2	2

Dependency	Rank
Not dependent	0
Partially dependent	1
Fully dependent	2

Table 26. Dependency of shrimp aquaculture activities on coastal resources

			Shrimp aquaculture activities								
			Larvae	Post larvae	Adults	Pacific white shrimp	Asian tiger shrimp	Chinese white shrimp	Americas	Asia	Africa
Resources	**Abiotic**	Salt	50	100	100	60	120	120	39	39	39
		Aggregates	0	0	0	0	0	0	0	0	0
		Coastal minerals	0	0	0	0	0	0	0	0	0
		Oil and gas	0	0	0	0	0	0	0	0	0
		Marine renewables	0	0	0	0	0	0	0	0	0
	Biotic	Fisheries resources	0	111	111	292	292	292	162	162	162
		Primary production	144	144	144	196	196	196	162	162	162
		Habitat condition / extent	0	206	206	260	260	260	162	81	162
		Biodiversity	114	228	228	300	300	300	162	162	162
		Bioprospecting	0	0	0	60	0	0	18	0	0
		Water quality	182	182	182	206	206	206	150	150	150
Vulnerability of activity			**201**	**327**	**327**	**505**	**468**	**468**	**477**	**414**	**459**

Table 27. The vulnerability of shrimp aquaculture activities to changes in coastal resources (rated 0-540)

Table 25 demonstrates that shrimp aquaculture is highly dependent upon biotic coastal resources - particularly primary production, water quality, biodiversity and habitat condition/extent. The overall quality of the coastal ecosystem is therefore a key influence on shrimp aquaculture. This dependency appears to hold true for all species and locations included in this study. Shrimp aquaculture appears to have very little dependency on abiotic resources, with the possible exception of salt. Table 26 presents the vulnerability of shrimp aquaculture to coastal resource change. It shows that shrimp aquaculture is highly vulnerable to changes in biotic resources, highlighting the importance of the health and productivity of the coastal system to productive shrimp aquaculture.

7.5 Governance of shrimp aquaculture

As shown in section 7.3 and 7.4, while shrimp aquaculture activities generate significant impacts on biotic coastal resources, shrimp aquaculture itself is also extremely dependent upon the quality of the same coastal ecosystems. This is a rather symmetrical governance situation, in which there is a clear self-interest for shrimp aquaculture to carefully manage its own impacts on coastal ecosystems in order to safeguard its own productivity. In order to assess the adequacy of land-sea governance arrangements, the following section considers the legal and voluntary arrangements, at various levels, for the governance of shrimp aquaculture with respect to impacts on coastal resources.

International and regional laws and guidelines

Sustainable and responsible aquaculture (in general) is governed by a range of international conventions and codes of conduct, including the Sustainable Development Goals, the Convention of Biological Diversity (CBD) and multiple ICES Codes of Practice. The FAO Code of Conduct for Responsible Fisheries and other guidelines provide a framework for national and international efforts to sustainably conserve and manage aquatic resources. At the national level, many countries have made efforts to improve aquaculture governance, but often lack policies, framework strategies and plans, and the implementation of legal measures is weak. In addition, there are often long time lapses between policy formulation, policy adoption and the formulation of concerted action plans. This means that strategies may no longer apply in rapidly changing circumstances (Satia, 2011). As such, Wurmann (2017) asserts that countries need to update their essential instruments in line with changes in the sector and promote participatory and inclusive mechanisms involving all stakeholder groups in the formulation of essential instruments and build capacity for the implementation of the instruments developed.

In contrast, the European Union is driving coordinated efforts to enhance sustainable aquaculture through: (i) The implementation of EU environmental legislation (the Marine Strategy Framework Directive), (ii) Maritime Spatial Planning with an ecosystem-based approach (iii) Strategic Guidelines for the development of the sector in the EU and National Strategic Plans by EU Member States, (iii) regular exchange of best management practices among EU Member States; (iv) support to the aquaculture sector to adopt more sustainable practices; and (v) support for research and innovation on different aspects to support the environmental performance of the aquaculture sector. Although there is no single monitoring and control system specific to aquaculture at the EU level, EU Member States require environmental monitoring and control of aquaculture activities. An environmental assessment is required for intensive aquaculture activities under EU legislation.

National governance arrangements

Most countries do not have a specific aquaculture policy as it is included in the remit of fisheries departments. Aquaculture development is mainly based on development plans elaborated by the sector's authorities but without formal approval. Participatory mechanisms involved in defining policy mostly take the form of unofficial consultations. The most common problem concerning the administrative aspects of responsible aquaculture is administrative overlap and interference. This problem arises from unclear regulation of the sector and a confused administrative situation (FAO, 2010). Some countries with significant large-scale aquaculture industries (including Japan, Thailand, some states of the United States and parts of Europe) do not apply environmental impact assessments to aquaculture development, but rather rely on a range of alternative environmental management procedures. In the United States, for example, a Code of Practice for aquaculture is included in US fisheries policies (Boehlert and Schumacher, 1997), whereas aquaculture development in Mexico is under the jurisdiction of the National Fisheries Charter - a legally binding instrument that supports innovative processes to foster use of native species and to avoid the use of exotic species (Alvarez-Torres *et al.*, 2002). In many African countries, the ability of individuals, companies, governments and development agencies to plan for aquaculture projects that are financially and environmentally sustainable is hampered by a lack of technical capacity, as well as scarce resources.

FAO (2010) advocates the adoption of an ecosystem approach to aquaculture at a national scale, as such an approach integrates aquaculture within the wider ecosystem (thereby promoting sustainable development, equity and resilience of interlinked socioecological systems). As such, the approach facilitates the adoption of international and national policies and regulations at a relevant geographical or administrative scale. This can involve the zoning of aquaculture to reduce conflicts with other users of aquatic resources and minimize negative environmental and social impacts; estimating the safe carrying capacity for aquaculture in an area; and undertaking some form of environmental impact assessment or risk assessment (particularly in relation to pollution, environmental disturbance and the introduction of invasive species). This approach would work well as part of a marine spatial planning framework. Sustainable aquaculture also needs good management and control, which can be enforced by regulators requiring regular environmental surveys, voluntary Codes of Best Practice and by licensing or certification schemes.

Industry initiatives and partnerships

Best management practices and performance standards have been used as a means of preventing unacceptable environmental damage and have often been developed by industry groups. These guidelines bring clarity and transparency to approval processes, while reducing conflict with other activities. Such guidelines focus attention and debate on substantive issues while minimizing the chances of conflicts developing around tangential issues. Such guidelines include environmental impact assessments; zoning, siting and monitoring criteria; and the identification of key indicators and environmental performance standards.

Conclusion

Given the focus on shrimp aquaculture in Asia, the Americas and Africa in this study, the following conclusions are only relevant to this form of aquaculture. It is clear that shrimp aquaculture, whether occurring on land or at sea, requires very careful and stringent management within a strong governance framework. The impacts of shrimp aquaculture on coastal resources (including other aquaculture activities) are significant and potentially long lasting. Given these considerations and the activity's linkages to other coastal activities and resources, the management of shrimp aquaculture must take place within an integrative framework that respects cross-sectoral and cross-border linkages and takes due account of them in management decisions.

One approach to sustainable shrimp aquaculture development is careful planning, zoning and prioritization of sites among the different potential users. Conflicts with other users and other economic activities (such as fisheries, agriculture, forestry, tourism and subsistence users) can be costly and can cause irreversible damage to ecologically and economically critical resources. Another approach is to promote aquaculture best practices. At the national level, this would include a national aquaculture policy, strategy, guidelines and action plan to be in place (including shrimp aquaculture). National aquaculture development processes should be transparent and take place within the framework of relevant national policies, regional and international agreements, treaties and conventions. Finally, research and technological innovations should be promoted to enhance shrimp and other forms of aquaculture sustainability through viable solutions, and to reduce physical, chemical, biological and social impacts.

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8

GOVERNANCE OF COASTAL RESOURCES AND THE SUSTAINABLE BLUE ECONOMY


Unsplash/Alex Duffy

8.1 Introduction

The principal aim of this report was to determine appropriate governance approaches to reduce the effects of land-based activities on coastal resources and support the transition to a sustainable blue economy. Governance in this study refers to the frameworks, processes, actors and ideas through which decisions and strategies are chosen and implemented (Oakerson, 1992; Kooiman *et al*., 2008). The complex cross-institution, cross-jurisdiction and cross-natural boundary character of the governance required to address the land-sea challenges highlights the challenge of governance in this sector. What is clear is that that any governance response must support coordinated outcomes that: respect the importance of land-based activities and coastal resources, protect the most vulnerable coastal resources and sustain healthy ocean economies that rely on living and non-living marine resources.

As presented in this report, the effects of land-based activities on coastal resources are complex and difficult to observe, as there are numerous potential pathways through which resources can be affected by land-based activities. The unique contribution of this study is to unpick the relationships between activities and resources, in order to identify, describe and quantify cumulative impact pathways. This understanding is of critical importance for the governance of resources that underpin the sustainable blue economy. As explained in chapter 1, this research draws from the existing scientific literature with its inherent strengths and weaknesses. In order to offset risks to the numerical analysis applied to the results of the literature-based evidence reviews, strong quality assessment and validation measures were adopted throughout the study.

The transition to a sustainable blue economy is a widespread objective of ocean governance, at the heart of which is the conservation of the biotic and abiotic resources that support 'blue' economic activities. At present, visions and approaches to the sustainable blue economy tend to focus on ocean-orientated governance approaches, with relatively little consideration of the possible influence of land-based activities. This chapter begins by synthesizing the key governance challenges identified through this study, before presenting a range of possible governance responses. The report concludes with governance recommendations intended to reduce the impacts of land-based activities on coastal resources while supporting the transition to a sustainable blue economy.

8.2 Synthesis of results

In this section, the results of the 'global' study of the relationships between a series of land-based activities and relevant coastal resources are combined with the case study analyses of extractive activities and shrimp aquaculture. This enables observations to be drawn across three comparable analyses.

The stressors generated by land-based activities are important, as these initiate impact pathways between an activity on land and coastal resources. From the three analyses presented in Table 28, it is clear that shrimp aquaculture generated the greatest influence upon both natural and non-natural stressors and generated stressors not created by other activities (such as genetic contamination of natural populations and the release of organic matter into the water column). This is because shrimp aquaculture systems depend on, and are part of, natural waters and food chains. As such, shrimp aquaculture can profoundly affect the coastal environment by modifying and affecting natural habitats, sediments, ecosystems, species and chemical composition. It is, however, important to remember that the extent of the stressors generated by shrimp aquaculture can depend upon the location of the production site, the stage in the aquaculture life cycle and specific site-level management practices. It should also be noted that, due to the close and visible link between shrimp aquaculture and the natural world, the body of evidence and research is generally stronger than for many other activities. In contrast, extractive activities have a relatively limited role in the generation of stressors, with the exception of increased sedimentation and the introduction of persistent toxins.


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Analysis	Average generation of stressors	
	Natural	Non-natural
Global	1.6	1.9
Extractive activities	1.4	1.4
Shrimp aquaculture	2.4	2.2

Table 28. Summary of average generation of stressors arising from land-based activities (maximum value of 3)

Table 29 compares the impacts of stressors on coastal resources. It shows that there is no significant difference in impact between the analyses, with the exception that shrimp aquaculture-generated stressors have reduced impacts upon abiotic resources compared to other stressors. However, the average impact on biotic resources is much greater than on abiotic resources in all three analyses. This is largely because the threshold for impact on abiotic resources is considerably higher than for biotic resources. As such, biotic resources are most vulnerable to stressors generated by land-based activities. From a governance perspective, this suggests that limiting the most influential stressors - including persistent toxins, sedimentation and plastics - should be the focus of governance interventions.

In order to compare cumulative effects, the results of the matrices showing the effects of land-based activities on coastal resources for each of the three analyses were standardized (on a scale of 0-50) then divided by the number of activities generating pathways. The results shown in Table 30 indicate that biodiversity, fisheries and habitat conditions are the coastal resources most impacted by cumulative effects arising from land-based activities, whereas coastal minerals, aggregates and genetic resources are the least impacted. Notably, while shrimp aquaculture was found to have the most impact on stressors, when viewed cumulatively across all possible impact pathways, extractive activities had a greater impact. On average, biotic resources were impacted nearly three times as much as abiotic resources and nearly six times as much in the case of shrimp aquaculture.

Analysis	Average impact on abiotic coastal resources	Average impact on biotic coastal resources	Average impact on all coastal resources by natural stressors	Average impact on all coastal resources by non-natural stressors
Global	0.7	2.2	1.6	1.5
Extractive activities	0.7	2.2	1.6	1.5
Shrimp Aquaculture	0.4	2.3	1.6	1.3

Table 29. Summary of the impact of stressors on coastal resources (maximum value of 3)

	Coastal resources										
Analysis	Salt	Aggregates	Coastal minerals	Oil and gas	Renew-ables	Fisheries	Primary Production	Habitat condition	Biodiversity	Genetic resources	Water quality
Global	9.0	4.7	0.0	5.5	9.7	21.2	16.3	20.2	23.0	7.2	17.5
Extractive activities	12.7	5.2	0.0	6.7	13.7	28.2	20.1	25.9	29.0	10.4	21.9
Shrimp aquaculture	9.4	4.2	0.0	5.5	11.0	21.6	17.0	20.0	21.9	7.4	16.9

Table 30. Cumulative impact pathways on coastal resources (rated 0-50).

As expected, Table 31 shows that extractive activities have a greater dependency upon abiotic resources than biotic resources, and that shrimp aquaculture is highly dependent upon biotic resources. Overall, shrimp aquaculture was found to be more vulnerable to coastal resource change caused by land-based activities than extractive activities. In terms of vulnerability to changes in biotic resources, shrimp aquaculture is, on average, 35 times more vulnerable to change in biotic resources than extractive activities. This is due to its high dependency on a wide range of biotic resources and the huge variety of cumulative impacts experienced by biotic resources.

Resource	**Global**	**Extractive activities**	**Shrimp aquaculture**
Salt	1	1	1
Aggregates	1	1	0
Coastal minerals	1	1	0
Oil and gas	1	1	0
Marine renewables	1	1	0
Fisheries resources	1	0	2
Primary production	0	0	2
Habitat condition and/or extent	0	0	2
Biodiversity	0	0	2
Genetic resources	0	0	0
Water quality	0	0	2

Table 31. The average dependency of blue economy sectors upon coastal resources (range 0-2).

8.3 Governance response

Governance implications

It is clear from this study that land-based activities generate multiple natural and non-natural stressors that impact the condition of coastal resources. Particularly impactful stressors were increasing concentrations of sediment (such as those from infrastructure development or poor land management), increasing concentrations of persistent toxins (including from mining runoff), increasing concentrations of plastic (for instance, from poor industrial production processes) and increasing concentrations of nitrogen and phosphorus (from, inter alia, poor agricultural practices). Agriculture, ports/harbours and aquaculture were the land-based activities with the greatest cumulative impacts on coastal resources, and should therefore be governance priorities. Sustainable blue economy sectors that depend upon coastal resources are vulnerable to changes in the coastal resource base generated by the stressors from sub-optimal management of land-based activities. Sectors that rely upon biotic coastal resources (such as fisheries, aquaculture and tourism) are especially vulnerable. In simple terms, if we want an equitable and sustainable blue economy to develop and flourish, governance structures must be developed to reduce the vulnerability of blue economy sectors to changes in the coastal resource base arising from poorly managed land-based activities.

As demonstrated by the case studies of extractive activities and aquaculture, governance arrangements that effectively take account of multiple land-sea impact pathways are not common. It was clear from the extractive activities case study that national governments have had mixed success in tackling the negative effects of terrestrial extractive activities and that the legislation in place is not always tailored to the land-sea context. It was also notable that voluntary partnerships are a key element of the extractive sector's approach to impact avoidance, particularly before extractive activity has commenced. However, given the profoundly damaging stressors generated by extractive activities, the effectiveness of voluntary approaches is questionable.

Similarly, shrimp aquaculture generates significant negative impacts on a range of biotic coastal resources (including other aquaculture activities), and therefore requires very careful and stringent management. Given that both extractive activities and shrimp aquaculture operate in a coastal context that is intensely used by a variety of other sustainable blue economy sectors, their management must take place within an integrative framework that respects cross-sectoral and land-sea linkages and takes due account of these and other trade-offs in management decisions. The absence of such a coordinating mechanism in the case studies was clear, as was a lack of capacity to adopt governance approaches and management actions that take adequate account of the effects of land-based activities on coastal resources. Perhaps more fundamentally, there is an absence of governance arrangements that adequately consider effects that: 1) connect activities that have tended to be managed separately and may be spatially distant; 2) cross the land-sea interface; and 3) cross national borders.

Governance challenges

In order to inform the development of governance recommendations, it is important to reflect on the broader challenges facing any governance approach that needs to encompass terrestrial and marine activities. However, this should be prefaced with the following assertion: the main responsibility for controlling the effects of land-based activities on coastal resources lies with the State where the land-based activity occurs. Where effects on coastal resources are within the same State, then the challenge is largely about consistency of national legal and voluntary approaches, and in the case of federal States it is consistency between national and provincial approaches. Where the effects lie outside of the State in which the land-based activity occurs, this requires international agreements to be in place, to address transboundary issues effectively, and for the agreement to be adhered to.

First, it is important to recognize that ocean health and sustainable resource use are closely linked to the achievement of broader environmental objectives within global frameworks such as the Convention of Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC), as well as wider sustainability objectives addressed within Agenda 2030 for Sustainable Development. Tackling challenges such as marine pollution (SDGs 14.1 and 6.3), for example, can increase the availability of marine resources for food and thereby contribute to eliminating malnutrition (SDG 2.2) (Singh *et al.*, 2018). Combating overfishing is also intricately linked to the attainment of other SDGs, such as tackling illegal labour practices (linked to SDGs 8.7 and 16.2) and maintaining fish stocks for future generations, thereby helping to preserve biological and cultural heritage (SDG 11.4) (Singh *et al.*, 2018).

Importantly, the relationship between land and sea-based targets may not always be positive and can potentially lead to trade-offs. Marine Protected Areas, for example, could compromise food security and targets linked to eliminating socioeconomic disparities (SDG 10) because local fishing activities and employment may be displaced when access to fishing areas is restricted (Singh *et al.*, 2018). While these issues can be alleviated in the long term through increases in fish abundance and the creation of alternative livelihoods (Lester *et al.*, 2009; Russi *et al.*, 2016), the management of potential short-term trade-offs requires careful consideration and full acknowledgement of impact pathways and interdependencies. A further challenge, demonstrated in relation to extractive activities in chapter 6, is asymmetric impact profiles, in which an activity is immune from the negative impacts it generates, thereby creating little motivation for changing behaviour. In such circumstances, strong governance is likely to be needed to support equitable trade-off outcomes for all interests. Finally, there is the need to consider disaster risk reduction strategies and build the resilience of coastal communities in the light of increasing risk from climate-driven extreme events.

Typically, however, effective management of coastal trade-offs is impeded by governance mechanisms that do not fully address land-sea interactions and associated broader considerations. Historically, governance frameworks in the terrestrial and marine environments have been organized around individual resources and uses, resulting in isolated pieces of legislation for specific policy areas such as transport, fisheries and pollution (Olsen *et al.*, 2006; Boyes and Elliott, 2014). Physical (land and sea) and jurisdictional boundaries (national and international) have played a key role in promoting this compartmentalized and piecemeal coastal resource governance approach. Furthermore, under the United Nations Convention on the Law of the Sea (UNCLOS), marine areas are divided into five main zones (Internal Waters, Territorial Seas, Contiguous Zone, Exclusive Economic Zone and the High Seas), each with a different legal status and resource accountabilities. This fragmented governance framework means that measures to address human impacts on the ocean have thus been adopted at different governance levels (mostly international, regional and national), resulting in sector-specific laws and agreements governed by numerous organizations and administrative bodies (Boyes and Elliott, 2014).

Despite the fragmented approach, UNCLOS does explicitly make provisions for pollution from land-based sources. For example, Article 207, clause 1, states that “States shall adopt laws and regulations to prevent, reduce and control pollution of the marine environment from land-based sources, including rivers, estuaries, pipelines and outfall structures, taking into account internationally agreed rules, standards and recommended practices and procedures”, and that States “shall take other measures as may be necessary to prevent, reduce and control such pollution” (clause 2) and “endeavor to harmonize their policies in this connection at the appropriate regional level” (clause 4). The extent to which these articles have proven successful is questionable, given the extent of the impacts described in this report. This raises the possibility of the need for a new international legal land-sea governance instrument.

In addition to this legislative remit, psychological boundaries may also play a role in impeding holistic governance structures, as threats to ocean health are often perceived as distant or abstract - particularly for a large share of the world’s population living in landlocked countries or far away from the coast (Schuldt *et al.*, 2016) or for individuals or sectors who believe their impacts are the responsibility of others to manage (Potts *et al.*, 2016). Given the challenging global context, it should be considered a priority to develop appropriate governance responses to address the profound impacts that land-based activities identified in this study have on coastal resources.

Existing governance approaches

This section of the report considers governance approaches with the potential, perhaps through adaptation or enhancement, to address land-sea impact pathways and thereby support the transition to a sustainable blue economy and associated desirable outcomes (such as disaster risk reduction). Although we fully recognize that attempts to coordinate land and marine governance systems have been made and are ongoing, we assert that managing land-sea connections is becoming ever more complex and challenging, and requires new or strengthened approaches to be developed to tackle this new situation. The push to transition to an equitable and sustainable blue economy creates additional urgency around how we can build economic priorities into land-sea governance approaches.

As noted by UN Environment (2018), area-based management approaches offer great potential to address transboundary and multi-sector resource challenges while also contributing to a wide range of SDG targets. Such transboundary approaches have been successfully implemented in different areas around the world, including on small islands in the Indian Ocean, the Lofoten-Barents Se, and in the Caribbean. More broadly, this is a focus of the UN Environment Regional Seas Programme (UN Environment, 2018), but largely in the absence of an explicit sustainable blue economy agenda. A dominant feature of these approaches is ecosystem-based management, which recognizes the world as a socioecological system consisting of human and natural processes that connect through space and time and are therefore governed holistically in order to generate sustainable outcomes.

Ecosystem-based management is widely recognized as a key concept underpinning the SDGs, due to its cross-sector and cross-disciplinary character. The ecosystem-based approach also places an emphasis on protecting the natural capital upon which the social and economic well-being of human communities depends. Ecosystem-based approaches, applied to coastal areas, may therefore deliver some of the key characteristics that this chapter identified as necessary to address the land-sea impact pathways. The emphasis on socioeconomic as well as natural system characteristics means that connections to the sustainable blue economy are more likely to be supported. Examples of governance approaches incorporating ecosystem-based management relevant to land-sea resource governance challenges include the following:

- Integrated Coastal Management is an approach in which the land and sea are managed as a unified zone and efforts are made to integrate policies and actions to ensure a coherent approach to coastal planning and management. Integrated Coastal Management approaches have been initiated worldwide (Wu *et al*., 2012). For example, in South-East Asia PEMSEA (Partnerships in Environmental Management for the Seas of East Asia) has supported over 50 active management sites and developed a Framework for the Sustainable Development of Coastal Areas and an Integrated Coastal Management Code to guide its work (PEMSEA, 2015). In the Mediterranean basin, the Mediterranean Protocol provides a framework for establishing ecosystem-based management and addressing human pressures and cumulative impacts in the coastal Mediterranean (UN Environment, 2018). Similarly, the development of the Campeche Bay Integrated Management Program in Mexico addresses problems affecting the coastal area (Fuentes *et al*., 2018). Despite some excellent examples, Integrated Coastal Management has had a mixed record of success – often due to limited government investment and its focus on challenging resource distribution patterns (often with limited legal or enforcement power).
- Ridge to Reef is an approach similar to Integrated Coastal Management in its philosophy, but its emphasis is narrower, being focused on connecting only salt and freshwater ecosystems in a unified governance approach. Ridge-to-Reef approaches typically focus on tackling land-based sources of pollution to conserve coastal resources (usually coral reefs). In Grenada, a ridge to reef approach has helped to develop incentive schemes to encourage good practice for upland agriculture and livestock activities to reduce polluted run-off degrading coastal ecosystems (UN Environment, 2018). While effective in situations of limited complexity and spatial scale, Ridge-to-Reef approaches alone are unlikely to be the solution to the land-sea governance challenges identified in this study. However, they may offer important learning opportunities related to the governance of individual impact pathways.
- Source-to-Sea approaches focus on connecting single or multiple river basins to the sea into which they drain through a structured and relatively fast process, building on existing governance approaches, to identify appropriate actions (Mathews *et al*., 2019). The Source-to-Sea approach seeks to establish governance, practice and finance connections that increase collaboration and coherence between terrestrial and marine water systems. The intention behind this is to reduce negative relationships between land and sea (including in relation to water, pollution, sediment, materials, biota, ecosystem services) and generate measurable economic, social and environmental improvements (Mathews *et al*., 2019). In broad terms, the Source-to-Sea approach is similar to the Ridge-to-Reef approach, although its more structured approach means it is

applicable to a broader range of natural and human settings. While generating interest as an approach to specific issues such as plastic pollution from land (Matthews and Stretz, 2019), practical testing of the Source-to-Sea approach appears limited, although it is noted that the marine litter, pollution and sewage-borne pathogens in the Bay of Bengal Large Marine Ecosystem are being tackled through a Source-to-Sea approach and the Pacific Islands Ridge-to-Reef National Priorities Program is also adopting a Source-to-Sea approach (Mathews *et al.*, 2019).

- Marine Spatial Planning is an approach to the strategic planning of coastal resources, including marine space, to achieve specific policy goals. Generally speaking, Marine Spatial Planning does not include any terrestrial areas and is restricted to marine waters, although the landward boundary can sometimes include intertidal areas. In the United Kingdom, Marine Spatial Planning focuses on the planning and management of marine resources and activities at sea with no role in land-based planning. The only exception is that both terrestrial and marine plans have reciprocal obligations to take each other's policies into account when making planning decisions. While this is not a unified governance structure in any sense, it does provide a model through which governance frameworks can be linked. Given that this study has identified the need to focus on land-based activities, it is unlikely that Marine Spatial Planning alone can provide the answer. Under the European Union's Maritime Spatial Planning Directive, all Member States with a coastline must have developed and implemented Maritime Spatial Plans by March 2021. Belgium has been a pioneer of MSP, implementing its 'Master Plan for the North Sea' in 2004 as a precursor to a comprehensive and detailed Marine Spatial Plan that was fully implemented in 2014. The Directive also requires Member States to consider land-sea interactions to ensure that there is a link between land and marine spatial planning.
- Marine Protected Areas are the primary mechanism for protecting important marine species and habitats from potentially damaging activities. The level of protection within a marine protected area broadly reflects the level of threat facing the designated natural feature(s). The management measures applied within marine protected areas tend to focus only on marine-based threats, as the legal remit of marine protected areas does not generally extend to terrestrial areas. The success of marine protected areas depends on effective land-based governance (and therefore risks) in the same way as coastal resources underpinning the sustainable blue economy. It is also important to note that areas designated for protection based on their ecological importance may not be the areas that generate substantial economic and social well-being for the sustainable blue economy, although there is clear evidence that marine protected areas can provide economic benefits (European Commission, 2018). The extent to which a marine protected area can safeguard marine resources will depend on what the designated area was intended to protect, and the management measures put in place to deliver the intended protection.

Although all have their weaknesses, these area-based management approaches may provide a basis for managing the dynamic relationship between terrestrial and marine areas, as well as supporting cooperation between agencies working in different realms and at different levels of authority. This has the potential to pave the way towards more effective management of human impacts on marine areas and resources. Other approaches that should be considered here include the following:

- Voluntary agreements put in place by industries or sectors can be effective with widespread uptake. For example, companies in some food supply chains are voluntarily reducing plastic (including packaging) in their production processes to reduce plastic pollution entering the ocean. Many private-sector organizations are framing their marketing and branding messages around environmental welfare and carefully considering how private sector actions can contribute to Sustainable Development Goals and other global targets. FAO produces many guides to voluntary practices that support more sustainable fishing and aquaculture practices. However, given the pervasive nature of land-based effects on coastal resources, it is unlikely that voluntary agreements and partnerships can generate the scale of change necessary across all key sectors globally.
- Environmental Impact Assessment is a common approach around the world to address the impacts on the environment associated with the establishment and operation of new developments. These assessments are triggered by various criteria, including scale of activity and proximity to vulnerable environments. While useful for identifying transboundary

environmental linkages of individual projects or groups of projects (including cumulative effects), environmental impact assessments are not well suited or widely used to manage the ongoing operational functions of multiple land-based activities. As such, their value as a possible platform for trade-off analysis and decisions focused on land-sea interactions is likely to be limited.

- International initiatives and partnerships can play an important role in framing the political context for governance change. A potentially key international partnership is the UN Environment Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, which was created in 1995 and has a membership of 108 countries. The goal of the Programme is to generate sustained and effective action by national governments to deal with all land-based impacts upon the marine environment. Since 2012, this has been delivered through three related initiatives:
  1) the Global Partnership on Marine Litter; 2) the Global Partnership on Nutrient Management; and 3) the Global Wastewater Initiative. At the Fourth Intergovernmental Review of the Programme, there was a commitment to strengthen all three initiatives - including the linkages between them. The UN Environment Regional Seas and Action Plans network also supports partnership working between coastal States and has a key role in tackling land and marine governance challenges that span international boundaries.
- Two other international marine-focused frameworks in Europe are the EU Water Framework Directive and the EU Marine Strategy Framework Directive. The EU Water Framework Directive, adopted in 2000, requires countries to create River Basin Management Plans to ensure all inland, estuarial and coastal waters achieve 'good ecological status'. These plans apply across boundaries in EU Member States. The EU Marine Strategy Framework Directive, adopted in 2008, takes a regional approach to the protection of Europe's marine environment by requiring Member States (individually but in consultation with adjacent States) to take action to achieve 'good environmental status', according to a series of descriptors. These coordination examples are broadly framed as an environmental rather than resource-focused activities, although both include a focus on addressing the effects of land-based activities.

8.4 Options for the enhanced governance of coastal resources

The following options for the enhanced governance of coastal resources are framed by the principles of resource efficiency (in which less resource input achieves the same or improved output) and decoupling (in which the negative environmental impacts are de-linked from economic growth), which are critical to achieving global goals and targets, as well as the transition to a sustainable blue economy. A key difference is that, here, these principles are applied to land-sea governance approaches. While the governance options are intended to identify specific approaches to coastal resource governance, we recognize that different approaches will be needed in particular places to reflect site and scale-relevant specificity. For example, the options may need to be adapted, combined or pared back to generate an appropriate governance response likely to be effective in specific conditions. The following governance options should therefore be seen as a suite of positive changes or interventions that can be tailored to scale-specific circumstances to enhance the governance of coastal resources and support the transition to an equitable and sustainable blue economy. The options have not been costed, and the order of their presentation does not suggest a prioritization. Given the particular vulnerability of living coastal resources from land-based activities, a particular emphasis has been placed on governance options that support marine biodiversity conservation. There is considerable practical experience of land-sea governance from which to draw in shaping these options, although little of it is explicitly framed by resource efficiency or decoupling.

The following governance options strengthen and reassert our existing understanding of effective practices in land-sea governance. These are:

- **Ecosystem-based management is the key guiding principle of coastal resource governance.** This approach recognizes the world as a complex and multilayered socioecological system consisting of human and natural processes that connect through space and time in multiple ways and need to be governed holistically to generate sustainable outcomes. Central to this approach is the need to have joined-up governance across sectors, jurisdictions and natural boundaries. This is critical to effective coastal resource governance and provides the basis for considering resource-efficient and decoupled solutions. Furthermore, the ecosystem approach places a high priority on: safeguarding natural capital that is critical to the sustainable blue economy agenda, building fair and equitable societies and supporting coastal disaster risk-reduction strategies. Considerable national level guidance already exists to support the practical implementation of ecosystem-based management, including UN Environment's introductory guide 'Taking Steps toward Marine and Coastal Ecosystem-Based Management' (UNEP, 2011).

- **Existing area-based management tools, with enhancement and adaptation, can be used to reduce the impacts of land-based activities on coastal resources.** Area-based management approaches enable specific management interventions to be applied to a defined area and are therefore key opportunities to tackle the negative impacts of land-based activities on coastal resources. Although many existing area-based management tools have narrow spatial or thematic remits, with suitable adaptation they could play a greater role in tackling and managing the impacts of land-based activities on coastal resources. Examples include Integrated Coastal Management, Ridge-to-Reef or Source-to-Sea approaches and Marine Protected Areas. These approaches already support ecosystem-based management while reflecting regional or local specificity.
- **Improved coordinating mechanisms can overcome fragmented land-sea governance.** A coordinating mechanism connects different governance frameworks and stakeholders to form a coherent governance approach. This does not necessarily replace pre-existing governance approaches but provides linkages between them. This then enables joined-up approaches to resource management to transcend individual governance frameworks. For example, agriculture generates significant impacts on fisheries, but at the national scale each sector is often governed independently. A coordinating mechanism will provide the link between these governance frameworks and enable coordinated responses to be developed to shared challenges - such as improved sediment control to avoid damage to nursery grounds for commercial fish stocks. The coordinating mechanism should be tailored to the prevailing legal, political, social and economic context and should focus on achieving improved resource efficiency and decoupling. At its simplest, it could take the form of a communication platform that provides space for knowledge sharing that promotes coordinated approaches between land-sea stakeholders and management regimes. A more sophisticated approach could include a conflict resolution mechanism to overcome disputes and potentially seek equitable outcomes arising from competing demands for terrestrial and coastal resources. Integrated Coastal Zone Management, Source-to Sea approaches and the UN Environment Global Programme of Action on the Protection of the Marine Environment from Land-based Activities deliver some elements of a coordinating mechanism - although each would require considerable strengthening to deliver the scale of governance change advocated in this report.
- **Capacity development programmes would support improved land-sea governance.** A capacity development package is needed to share international experiences, identify effective practices and provide learning materials for policymakers and practitioners involved in land-sea resource governance. This needs to be delivered in socially and culturally nuanced forms and should focus on local priorities. One emphasis of this capacity building approach would be how existing governance tools and approaches could be adapted or refined to better support land-sea governance and take account of seemingly distant land-based activities on coastal resources. Given the requirement to tackle weak governance of land-based activities that affect biotic coastal resources in particular, it would be important to ensure that capacity building is targeted towards those involved in land-based activities, as well as coastal governance practitioners. In addition, support to build research and development capacity that specifically seeks to reduce the impact of land-based activities on coastal resources would be important – potentially though university, private sector and government partnerships.
- **Filling evidence gaps, particularly related to the impacts of land-based activities on abiotic coastal resources, should be prioritized.** This study has demonstrated that there are significant gaps in our understanding of linkages between land-based activities and coastal resources, particularly in terms of abiotic coastal resources and the impact of newer stressors (such as plastics) on coastal resources. Furthermore, the evidence for the connection between coastal resources and sustainable blue economy sectors is rather limited. Ecosystem service and natural capital assessments exist, but these are rarely at

the sector-scale and so fail to capture the broader sweep of the links between coastal resources and the blue economy. Evidence gaps should be prioritized then addressed through systematic and targeted research activities. Without filling the evidence gaps, there is a risk that land-based activities will continue to have negative implications for coastal resources and potentially, where a precautionary approach is taken, land-based activities might become over-restricted in the mistaken assumption that they generate negative impacts on coastal resources. Similarly, there are gaps in our understanding of which governance approach is likely to be most effective in a specific circumstance. These gaps are further complicated by the dynamic external context in which new governance challenges may arise or become evident over time. Ongoing assessments of land-sea governance effectiveness will help develop an evidence base of 'what works' and why. These lessons can then be shared, with a view to improving the performance level of land-sea governance wherever it is needed. A strong horizon-scanning role may also help to pre-empt necessary governance arrangements and to explore and test possible responses.

The following governance options offer new insights into land-sea resource governance approaches framed around resource efficiency and decoupling. These are as follows:

- **Coastal governance should focus on the pathways connecting multiple land-based activities to coastal resources and should not be constrained by arbitrary boundaries.** This study has demonstrated that single and cumulative impact pathways exist between land-based activities and coastal resources, and that governance focused on any single activity has limited influence on the condition of coastal resources. We have also noted that there are different priorities in particular places and that fragmented governance systems that consider terrestrial and marine activities and resources separately are unlikely to be effective. We therefore recommend that the governance response is focused on the pathways connecting land-based activities and coastal resources and is not constrained by existing natural or administrative boundaries. This places resource linkages at the heart of the governance approach and places greater emphasis on the safeguarding of natural resources. This approach also reduces the effect of administrative or legal boundaries on resource governance (at least as far as resource efficiency is concerned). This is summarized in Figure 11.
- **Regional regulatory frameworks should be used to reduce the impact of land-based activities on coastal resources.** In order to develop impact-pathway focused governance approaches that reflect scale-specific conditions, we suggest the development of regional regulatory frameworks. This option is particularly useful in contexts where impacts on coastal resources are not considered in any other way and when land-based activity is disconnected from, or at a great distance from, impacts on coastal resources. Regional approaches enable tailored solutions for different places and can reflect the need for nation-specific governance responses. The process-driven elements of Integrated Coastal Management and Source-to-Sea approaches would be a good starting point for a regulatory system, as both require extensive stakeholder engagement and advocate joined-up land-sea governance. Any new regulatory frameworks should take the opportunity to adopt impact pathways as their unit of governance and place a legal obligation on land-based activities (and possibly sea-based activities too) to take account of coastal resource impacts in their planning and operational decisions. The UN Environment Regional Seas Programme and Action Plans are ideally suited to provide the legal basis for such new regulatory frameworks, and there is already some experience to draw from - particularly the work of HELCOM (the Baltic Marine Environment Protection Commission).
- **Natural capital safeguarding on land and at sea is a unifying principle.** Natural capital can be described as the natural features (living and non-living – such as coral reefs, forests and gravel beds) that underpin human well-being through the production of services that benefit society (such as food, flood protection and materials). This report has highlighted the importance of safeguarding coastal natural capital from the damaging impact of land-based activities in order maintain and enhance the resources upon which many ocean industries depend. As the case studies demonstrated, management interventions on land that benefit coastal natural capital also protect natural terrestrial capital and promote more resource-efficient land-based activities. Therefore, safeguarding natural capital on land and in the ocean should be seen as a unifying governance principle that generates positive outcomes on land and at sea and for all parties. In practice, this requires actions on land and in the sea to be considered as occurring within the same resource system, which is consistent with the ecosystem-based approach.

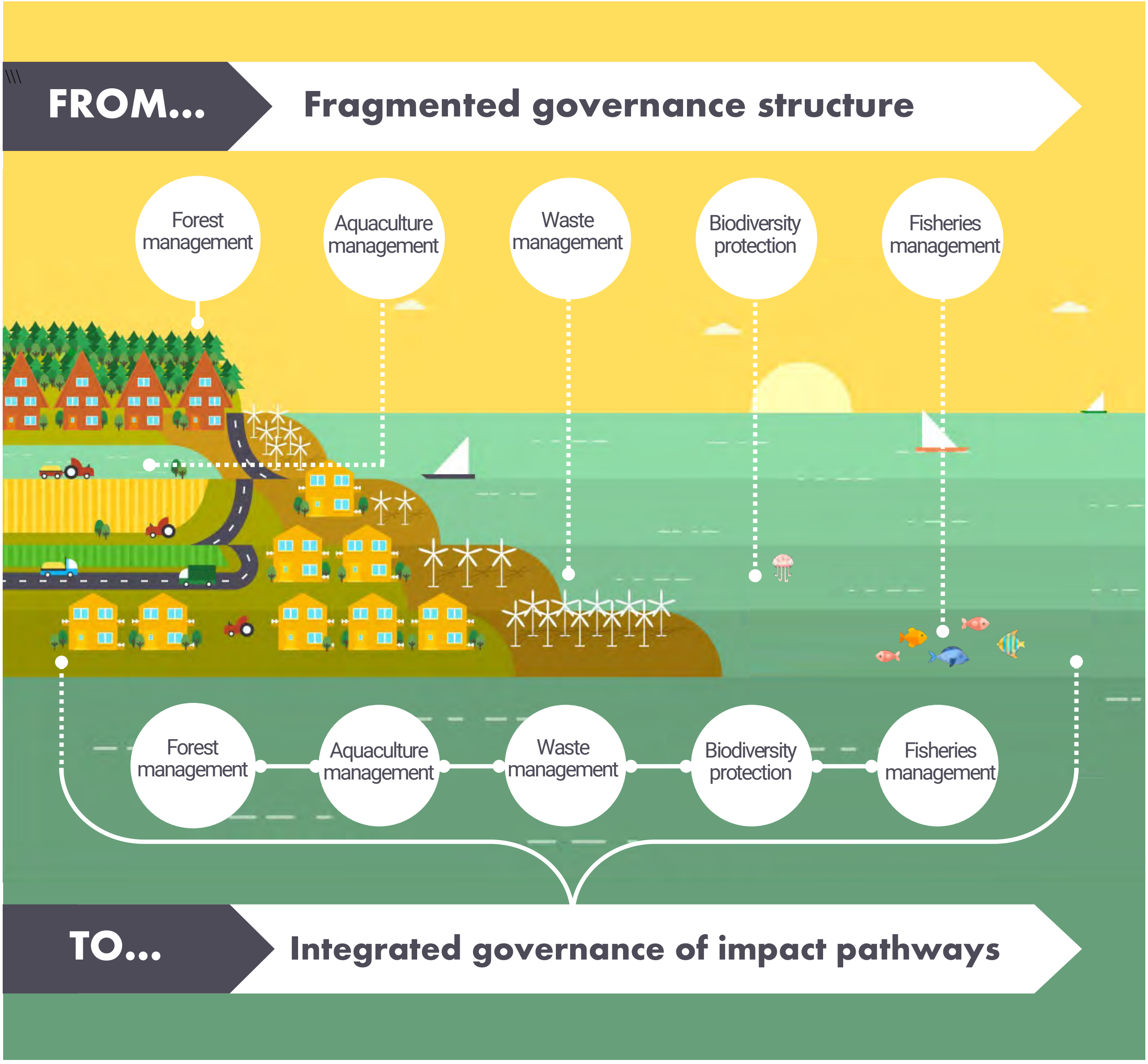

Figure 11. Improved coastal resource governance through integrated governance pathways

- **Coastal natural capital needs to be mapped and protected.** Locating coastal natural capital is potentially difficult as it may not overlap spatially with marine protected areas that are generally designated for specific ecological or conservation reasons (such as the rarity or representativeness of a certain habitat or species). For example, an area of unremarkable coastal gravel beds may not justify protection based on its ecological or conservation value, but it may be an important nursery ground for locally caught commercial fish stocks that, if degraded due to land-based (or other) activities, would create considerable economic hardship to the dependent human community. Coastal natural capital areas can be identified by modifying the blue economy sector dependence matrices herein and using existing spatial data to identify where those resources are located. Once identified, it is important to protect areas of high natural capital value. This will require a new form of protection that complements existing designations and that is specifically focused on protecting natural capital. While this represents a departure from existing protected area designation practice, it is not intended to diminish the importance of protecting areas for their ecological and conservation value and could be considered as a justifiable extension of the reasons to designate protected areas.
- **A stakeholder community must be constructed that reflects the pathways connecting land-based activities to coastal resources.** While stakeholder representation and engagement are well recognized as important components of

strengthening coastal governance approaches, this is not adequate for the proposed impact pathway-focused governance approach advocated here. Instead, a new stakeholder community must be built, as engagement is required from all land-based and sea-based stakeholders whose actions are located within an impact pathway. This may include stakeholders located hundreds of kilometres from the coast, stakeholders involved in activities seemingly peripheral or entirely disconnected from coastal resources and with different interests, experiences and ways of working. This will require substantial engagement from the private sector, government at multiple levels and many public and community interest organizations. Catalysing a shared ambition to safeguard terrestrial and coastal natural capital for mutual benefit will be critical to generate interest, support and the necessary trust for this scale of stakeholder engagement. Nuanced and well-targeted communications will be needed, as will professional and expert facilitation. A legal basis for such partnerships may be useful in circumstances where resource conflicts are prevalent or anticipated. Building a stakeholder community of the sort suggested would be a significant challenge that should not be underestimated. It will therefore be important to learn from and build upon existing experiences of stakeholder engagement at the global scale, such as the UN Environment Global Programme of Action on the Protection of the Marine Environment from Land-based Activities, or at the regional scale, such as PEMSEA (Partnerships in Environmental Management for the Seas of East Asia).

- **Monitoring and evaluation should focus on impact pathways.** Governance approaches require a monitoring and evaluation framework to enable their effectiveness to be determined and adaptations made to ensure their continued impact. As the proposed governance framework is focused on impact pathways, our view is that the monitoring and evaluation framework should also be focused on impact pathways. Therefore, rather than focusing simply on changes in the level of coastal resource availability as measures of success, the monitoring and evaluation framework would focus on changes in drivers, pressures, state and impacts. This would draw in multiple stakeholders, sectors and institutions to consider the effectiveness of the governance approach across the whole impact pathway(s). This would also enable cumulative factors to be taken into account by considering multiple impact pathways.
- **A decision-support tool is required to support land-sea governance approaches focused on impact pathways**. Decision-making related to any coastal resource affected by land-based activities is difficult. As such, the process could usefully be informed by a clear appreciation of the impact pathways and governance connections, along with an appreciation of the implications of any land-based decision for a coastal resource or blue economy activity. An online tool that converts the analysis presented in this report to an interactive platform to identify connections between land-based activities and coastal resources (and blue economy sectors) and potentially quantify them (in resource and monetary terms) would be the first of its kind and provide a significant practical step towards taking account of coastal resources in land-based activities. Given the complex relationships between land-based activities, coastal resources and the blue economy, as well as the gaps and uncertainties in the evidence base outlined in this report, the tool could helpfully be based on a relational model. In addition to mapping the relationships, this would also provide measures of uncertainty in the modelled relationships. This would enable users to appreciate the connections and trade-offs they needed to consider while also providing a measure of the quality of evidence underpinning the analysis.

8.5 Conclusion

This report has highlighted the complex relations between land-based activities and coastal resources and made a case for strengthened governance approaches that reduce the negative impacts on coastal resources arising from land-based activities, while supporting the positive transition to an equitable and sustainable blue economy. This transition is in part a vehicle to deliver multiple benefits to ocean and coastal communities, including fairly distributed social and economic benefits, improved disaster risk reduction and climate adaptation strategies, as well as contributions to multiple Sustainable Development Goals. Given the importance of women in coastal communities, the transition to a sustainable blue economy is also a key opportunity to drive towards gender equality in the blue economy. At the heart of these ambitions is the need to ensure that the coastal natural capital upon which much of the sustainable blue economy depends is safeguarded against the unintended impacts generated by land-based activities.

The land-sea relationship is the dominant recurring theme of this report in terms of both natural connections (such as river basins discharging into the sea or intertidal habitats that span the land-sea divide) and human connections (such as mass tourism to coastal areas or the reliance on marine protein for food security). In reality, it is not possible or useful to separate the natural from human land-sea connections, as there are both natural and human dimensions to all coastal resource challenges. For example, polluted river discharge can undermine the tourism economy and the over-exploitation of fish stocks can degrade key habitats that protect communities against natural hazards. The relationship between land-based activities and coastal resources therefore requires particular attention in terms of developing a greater understanding of their interconnections and developing models of governance that better respond to the challenges inherent to land-sea interactions.

In terms of improved understanding, the new methodology developed and applied in this study to better describe and communicate the relationships between land-based activities and coastal resources has proved to be useful at both the generic global scale and within the specific examples of shrimp aquaculture and extractive activities. The approach enabled individual and cumulative effects to be identified, along with the strength of the evidence base underpinning each assessment. This is an important new synthesis of this critical information. A key challenge was the sheer time required to determine the scale and direction of each relationship between an activity, the stressors it generates and the effects of those stressors on multiple coastal resources. It must also be recognized that this approach can lead to oversimplifications of what are often complex, spatially distinctive and dynamic relationships. The introduction of regional, national or site-level assessments will therefore be necessary in future assessments to generate more nuanced results.

The analysis of existing governance approaches, in light of the connections between land-based activities and coastal resources and in the context of the ambitions to transition to an equitable and sustainable blue economy, showed that improvements to coastal governance are needed. A key challenge in developing governance recommendations is variation in governance institutions, frameworks, practices and effectiveness between (and often within) nations and sectors. A further challenge is that the coastline itself is commonly used as a legal and administrative boundary, with often radically different governance systems are applied to the terrestrial and marine sides of the dividing line. This results in fragmented governance systems within nations, and these impede coordinated action to reduce the effects of land-based activities on coastal resources. This problem is magnified when land-based activities originate in other countries or contribute to the degradation of coastal resources at a regional scale.

Given the complexity of the relationships between the natural and governance connections in coastal areas, simple solutions are rarely available. This study has sought to develop governance options that build on existing institutions and structures, while also providing an enhanced focus on improving the relationship between land-based activities and coastal resources, thereby safeguarding the natural capital that underpins the transition to an equitable and sustainable blue economy.

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About the International Resource Panel

Aim of the Panel

The International Resource Panel was established to provide independent, coherent and authoritative scientific assessments on the use of natural resources and their environmental impacts over the full life cycle. The Panel aims to contribute to a better understanding of how to decouple economic growth from environmental degradation while enhancing well-being.

Benefiting from the broad support of governments and scientific communities, the Panel is constituted of eminent scientists and experts from all parts of the world, bringing their multidisciplinary expertise to address resource management issues. The information contained in the International Resource Panel's reports is intended to:

- be evidence based and policy relevant,
- inform policy framing and development, and
- support evaluation and monitoring of policy effectiveness.

Outputs of the Panel

Since the International Resource Panel's launch in 2007, more than 30 assessments have been published. The assessments of the Panel to date demonstrate the numerous opportunities for governments, businesses and wider society to work together to create and implement policies that ultimately lead to sustainable resource management, including through better planning, technological innovation and strategic incentives and investments.

Following its establishment, the Panel first devoted much of its research to issues related to the use, stocks and scarcities of individual resources, as well as to the development and application of the perspective of 'decoupling' economic growth from natural resource use and environmental degradation. These reports include resource-specific studies on biofuels, water and the use and recycling of metal stocks in society.

Building upon this knowledge base, the Panel moved into examining systematic approaches to resource use. These include looking into the direct and indirect impacts of trade on natural resource use; issues of sustainable land and food system management; priority economic sectors and materials for sustainable resource management; benefits, risks and trade-offs of low-carbon technologies; city-level decoupling; and the untapped potential for decoupling resource use and related environmental impacts from economic growth.

Upcoming work

In the forthcoming months, the International Resource Panel will focus on scenario modelling of natural resource use, the socioeconomic implications of resource efficiency and the circular economy, the role of resources in environmental displacement and migration, and the connections between finance and sustainable resource use, among others.

More information about the Panel and its research can be found at:
Website: www.resourcepanel.org
Twitter: https://twitter.com/UNEPIRP
LinkedIn: https://www.linkedin.com/company/resourcepanel

Contact: unep-irpsecretariat@un.org

GOVERNING COASTAL RESOURCES

IMPLICATIONS FOR A SUSTAINABLE BLUE ECONOMY

Coastal resources - including fish, minerals and energy - are critical to people, nature and the economy, and are a focus for the emerging sustainable blue economy agenda. It has long been recognized that a particular challenge in coastal areas is the management of land-based activities that generate detrimental impacts on coastal resources in the marine environment. Many of these pressures are negative externalities of land-based human activities that are not taken into account within existing resource-governance frameworks. Therefore, the development of improved approaches to land-sea governance that take account of how land-based activities affect the quality and availability of coastal resources is the focus of this report.

This global study used a Drivers, Pressures, State, Impact, Response (DPSIR) framework to assess how global scale drivers are pushing the development of land-based activities (pressures), which in turn affect the quality and availability (state) of coastal resources. The impact of changing coastal resources on a selection of sustainable blue economy sectors was then considered. Following a review of existing coastal governance approaches that support land-sea coordination, and a detailed evaluation of the governance arrangements in the extractive and aquaculture sectors, the study presents an analysis of possible governance responses that can better account for, and ideally reduce, the effects of land-based activities on coastal resources and thereby support the transition to a sustainable blue economy.

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