1. Overall assessment and recommendations

Chapter 1 summarises the main findings and recommendations of the OECD report "Rethinking Innovation for a Sustainable Ocean Economy". It emphasises the growing importance of science and technologies in improving the sustainability of the ocean economy. It then identifies three priority areas for action: 1) encourage innovation approaches that produce win-win outcomes for ocean business and the ocean environment; 2) seek ways to foster the creation and nourish the vitality of ocean-economy innovation networks; and, 3) support new pioneering initiatives to improve measurement of the ocean economy.

1.1. The crucial role of innovative approaches for a sustainable ocean economy

The ocean and its resources are increasingly recognised as indispensable for addressing the multiple challenges that the planet faces in the decades to come. By mid-century, enough food, jobs, energy, raw materials and economic growth will be required to sustain a likely population level of between 9 and 10 billion people. The potential of the ocean to help meet those requirements is significant, but fully harnessing it will require substantial expansion of many ocean-based economic activities. That will prove challenging, because the ocean is already under stress from over-exploitation, pollution, declining biodiversity and climate change. Indeed, ocean health is declining rapidly in many parts of the world, with dramatic socio-economic consequences. Dealing with these challenges calls for fresh thinking in many areas. The time is ripe therefore to explore innovative approaches as many changes are unfolding both in the ocean and in the ocean-based science, research and innovation (STI) policy landscape.

1.1.1. A conducive policy context to test new approaches

The last few years have seen a growing awareness of the importance of ocean sustainability issues, which has led to numerous new ocean initiatives at national, regional and global levels. In parallel, the much broader science, research and innovation (STI) policy landscape has been evolving rapidly, driven by the emergence of a host of new technology developments, by digitalisation, and by a resetting of priorities in national research agendas. Taken together, these changes offer an abundance of opportunities to develop innovative approaches for a sustainable ocean economy.

In less than a decade, the ocean has become a priority for many OECD and developing countries around the world, as it is increasingly recognised as an important source of economic growth and employment. At the same time, there is a growing realisation that the ocean is a fragile environment on which humanity depends for its climate, its weather, and – especially in coastal regions – for its very survival. Over-exploitation, pollution of all kinds from human activity, and climate change all contribute to undermining both the long-term stabilising effects of the ocean, and the socio-economic gains that it can yield, if used responsibly (OECD, 2016[1]).

In this context, the number of ocean governance-related initiatives at national, regional and global levels has multiplied. To name but a few, they include: the establishment of a specific ocean-related United Nations (UN) Sustainable Development Goal 14, with targets as early as 2020 (Box 1.1); the holding of a large-scale UN Ocean Conference in 2017 in New York; the announcement of a new UN Decade of Ocean Science (2021-30); the forthcoming (2019) publication of the first-ever report by the Intergovernmental Panel on Climate Change on the ocean and cryosphere, which will provide crucial information on the health of the ocean; the start in September 2018 of the negotiations on an international agreement to protect marine biodiversity in areas beyond national jurisdiction (ABNJ) in the high seas; and ongoing efforts by European countries to establish by 2020 the targets and indicators necessary to achieve Good Environmental Status under the European Union's Marine Strategy Framework Directive. A plethora of ocean-related conferences and other major events are also being held, organised by a wide variety of stakeholders from industry, academia, government and civil society.

All such ocean-related initiatives are occurring at a time when STI activities themselves are undergoing major changes (OECD, 2018[2]). Galvanised by digitalisation, the transformation of scientific research and innovation processes is speeding up in many parts of the world, in almost all disciplines and sectors of the economy. The adoption of disruptive technologies (e.g. artificial intelligence, big data, blockchain) is starting to affect academic research and business innovation cycles alike. The promotion of collaborative and open innovation is also changing the way researchers are training and working together (OECD, 2017[3]). At the policy level, a number of national research agendas are increasingly emphasising the need to tackle "grand challenges", in economic, societal and environmental areas. In some countries, this new focus takes the shape of mission-oriented STI policies, steering the direction of science and technology towards ambitious and socially relevant goals, with Sustainable Development Goals re-shaping in some cases STI policy agendas (OECD, 2018[2]).

Box 1.1. SDG 14 "Life below Water" with direct implications for science and technology

The SDG 14 aims to conserve and sustainably use the oceans, seas and marine resources for sustainable development. Its targets includes:

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

14.A Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries.

Source: United Nations (2018[4]), *Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development,* United Nations Statistical Commission, 49th session, A/RES/71/313, New York, March.

As the OECD report on *The Ocean Economy in 2030* emphasised, realising the full potential of our seas and ocean will demand responsible, sustainable action on numerous fronts and the achievement of a durable balance between ocean use and marine ecosystem integrity (OECD, 2016[1]). While such actions will necessarily encompass initiatives in a range of policy areas – from regulatory and structural reform to changes in environmental policy and governance – developments in STI will continue to play a crucial part in addressing many of the challenges facing our seas and ocean.

1.1.2. Summary of the fresh approaches proposed in this report

Putting the focus on STI highlights fresh approaches that may help tackle the challenges of achieving a sustainable ocean economy. With that in mind, this publication sets itself four objectives:

- Offer a forward-looking perspective on scientific and technological innovation across a range of marine and maritime applications, with a particular focus on some of the innovations already in the pipeline (Chapter 2);
- Contribute to the growing body of evidence suggesting that, with the help of innovation, the development of ocean-based economic activity and sustainability of marine ecosystems can go hand in hand with one another, and provide a number of in-depth case studies that illustrate the potential for generating such win-win outcomes; (Chapter 2)
- Investigate the emergence of different forms of collaboration in the ocean economy across research communities in the public sector, the academic world and a diverse range of private-sector stakeholders, using the example of innovation networks that have sprung up in recent years around the world (Chapter 3);
- Highlight new approaches to measuring the ocean economy, notably by exploring the use of satellite accounts for its twin pillars – ocean-based economic activities and marine ecosystem services – and by examining ways to better measure the benefits that important sustained ocean observations provide not only to science, but also to the economy and society more generally (Chapter 4).

On the basis of the analysis presented in this report, three priority areas for action are recommended and summarised in the follow-up sections:

1. Encourage innovation that produces win-win outcomes for ocean business and the ocean environment;
2. Seek ways to nourish the vitality of ocean-economy innovation networks;
3. Support new initiatives to improve measurement of the ocean economy.

1.2. Encourage innovation that produces win-win outcomes for ocean business and the ocean environment

The ocean is being used more intensively than ever before, raising questions about its physical and biological capacity to cope. At the same time, however, scientific understanding of the ocean and its ecosystems – their properties and behaviour, their health and role in weather and climate change – is gradually improving. To respond effectively to the growing challenges associated with the development of economic activity in the ocean, increased attention must be paid to the possibilities for greater interaction and stronger synergies between ocean-related science on the one hand and ocean business on the other.

1.2.1. Recent acceleration of research interests in ocean-related innovations and their applications

The breadth and depth of scientific and technological advances in today's ocean economy are the product of a flourishing, highly dynamic innovation landscape. *The Ocean Economy in 2030* report noted a string of enabling technologies with the potential to improve efficiency, productivity and the cost structure of many ocean-based activities in the coming decades. Scientific research, shipping, energy, fisheries and tourism are but a few examples of the activities likely to be impacted (OECD, 2016[1]). The enabling technologies highlighted in the report include imaging and physical sensors, advanced materials, autonomous systems, biotechnology, nanotechnology and subsea engineering. In addition, there are a range of likely disruptive and step-change innovations combining multiple technologies and finding application in activities as varied as ocean floor mapping, smart shipping, and tracing fish stocks and fish products. Considerable potential therefore resides in leveraging technology synergies across scientific disciplines and among different ocean sectors.

The update provided by the present report suggests that, in the years since the publication of *The Ocean Economy in 2030*, there has been a further acceleration of interest in the potential applications of a range of technologies, both for commercial purposes and for gaining a better understanding of marine ecosystems, their workings, and the requirements for their better management. It notes an increasingly pervasive spread, throughout the ocean domain, of such generic technologies as artificial intelligence, big data, complex digital platforms, blockchain, drones, sophisticated arrays of sensors, small satellites, genetics, and acoustics. All appear set to contribute in important ways to the sustainable development of the ocean economy, not least by vastly improving data quality, data volumes, connectivity and communication from the depths of the sea, up to the surface for further transmission.

1.2.2. Innovations that may foster both ocean-based economic development and environmental sustainability

Looking beyond the general picture of recent advances in science and technologies, a focal point of the report concerns innovations, and combinations of innovations, which may have the capacity to foster both ocean-based economic development and environmental sustainability.

To do this, it presents four in-depth innovation case studies that help draw some interesting lessons. The case studies were chosen because of the high interest they generate in different parts of the world and their different levels of technical and business maturity. The four case studies are: floating offshore wind power; advances in ballast water treatment to combat the spread of (alien) species; innovations in the marine aquaculture sector which contribute to making the industry more economically and environmentally sustainable; and, conversion of decommissioned oil and gas rigs and renewable energy platforms into artificial reefs.

The four case studies also differ in the scale of the respective activity. Floating wind power is still in its infancy, with only one commercial-scale facility in operation in the world. Ballast water treatment technologies have so far been installed in only a small number of ships, but expansion could be rapid when the international convention regulating ballast water is fully implemented. Oil and gas rig conversion into artificial reefs is current in some parts of the world, but not in others, and no renewables-to-rigs programmes exist anywhere. Marine aquaculture, by contrast, is well established in many parts of the world, is undergoing rapid expansion, and is being transformed at great speed by a whole host of innovations. For this reason the marine aquaculture case study is addressed in more detail and at sector-wide level. Moreover, innovation in the four activities is driven by different forces and different challenges. Despite these differences, examination of innovation activity in the four areas reveals that they share many common features.

Innovations in marine sectors are science-led and often interconnected

Progress in all four areas has clearly been science-led or at least science-based, underlining the vital role that science plays in the ocean economy. Moreover, the innovations are seldom "stand-alone" innovations. Rather, they develop in combination with – or at least in association with – other innovations and technologies.

Table 1.1. Step change progress in the development of sustainable ocean activity requires multiple innovations from different disciplines and sectors

Floating offshore wind farms	Progress in ballast water treatment in ships	Advances in marine aquaculture	Rigs and renewable energy platforms to reefs
Siting (eg. satellite remote sensing + modelling)	Detection of organisms & bacteria (e.g. lab-on-chip techniques, new-generation DNA etc.)	Siting/area-wide assessment (earth observation high spatial resolution; GIS mapping + modelling)	New types of well plug
New construction materials and methods (e.g. rotor blades, foundations)	Conventional disinfection processes (e.g. ultraviolet irradiation, electro-chlorination)	Breeding (selective breeding, genome sequencing, marker assisted selection)	Subsea vehicles for survey and inspection
New designs (e.g. twin hulls/multi-turbine arrays, dynamic cable systems)	New environmentally friendly treatments, e.g. pasteurisation	Feed (micro-algae, plant- and insect-based, fish oil replacements)	DNA barcoding, population fingerprinting for connectivity analysis
Inspection, maintenance & repair (e.g. AUVs / ROVs, AI-driven monitoring)		Waste management (IMTA, sensor-platforms, decision algorithms) and disease control (eDNA tools, mass spectrometry +AI, use of cleaner-fish)	For renewables – ecosystem impact modelling of biomass aggregation
		Open ocean engineering	Network analysis and modelling tools

The steep falls in the cost of energy expected in floating offshore wind turbines, for example, will stem from improved siting with the help of satellite data, from new foundation designs, use of composite materials in turbine blade manufacture, and deployment of marine automated unmanned vessels (AUVs) and remotely operated vehicles (ROVs) for monitoring, inspection, maintenance, and repair of offshore facilities. In marine aquaculture, multiple approaches are being brought to bear on the problem of disease prevention, control and treatment, ranging from advances in breeding for greater disease resistance (e.g. marker assisted selection) and new generation of vaccines, to hyperspectral analysis for detecting lice infestations. And in ships' ballast water treatment, research has given rise to hundreds of different applications that use a variety of underlying technological principles ranging *inter alia* from ultra violet, oxidation and de-oxygenation, to electrolysis, ultrasound and heat.

The economic stakes for ocean economy innovations are high

From an economic and business perspective, the innovations and combinations of innovations under way may be associated with significant potential gains. And selected sector-specific innovations tend to generate spillover benefits for other sectors of the ocean economy.

In terms of potential sector-specific gains:

- Floating offshore wind farms could in the longer term provide a further boost to the already rapidly expanding world market for offshore wind power as a whole – projected to generate by 2030 around USD 230 billion in global value added and 435 000 full-time jobs (OECD, 2016[1]);
- The potential global market for ballast water management systems – based on a range of different scenarios and assumptions concerning the number of retrofitted vessels and average cost per refit – is estimated to be in the order of USD 50 billion (OECD, 2017[5]);
- In the marine aquaculture sector, the cumulative effect of innovations promises to be an important contributing factor in enabling gross value added to grow at well over 5% per year, trebling the sector's value between 2011 and 2030 to around USD 11 billion (OECD, 2016[1]);
- Thousands of oil and gas platforms will need to be decommissioned in the coming decades. Reef creation requires leaving at least part of the infrastructure in place if fish, molluscs and other marine life are able to thrive. Partial removal of the infrastructure, as opposed to almost complete removal, could save the operators billions of dollars in decommissioning costs.

In addition to potentially providing economic benefits for their respective ocean industry, the innovations and combinations of innovations described here tend to generate spillover effects for other sectors of the ocean economy. These spillover effects may take the form of further technology development or the transfer of technology to other sectors, or, more generally, they may lead to further economic activities in neighbouring sectors.

By way of illustration, economic benefits from the accelerated deployment of floating offshore wind farms are expected to flow to ports, shipbuilders, and marine equipment suppliers and operators. Initiatives to encourage the conversion of oil and gas rigs and offshore renewable energy platforms to reefs have the potential to benefit the capture fisheries and aquaculture industries, downstream offshore services, and remote and autonomous marine vehicles' activities. More widespread uptake of ballast water treatment processes stands to benefit marine equipment suppliers and the shipbuilding and repair business industries. And sustainable expansion of marine aquaculture promises economic gains for downstream sectors such as the seafood processing industry, as well as upstream services and inputs such as cleaner-fish breeders, providers of remote sensing and inspection equipment, and suppliers of aquafeed and supplements – a global market already estimated at well over USD 100 billion in 2017 and projected to reach over USD 172 billion by 2022 (Research and Markets, 2017[6]).

The benefits to marine ecosystems could be significant but are still hard to quantify

The benefits to marine ecosystems stemming from these innovations are highly diverse and difficult to quantify. However, a summary of the types of ecosystem benefits likely to be realised is provided below.

Direct benefits to marine ecosystems are identifiable in all of the cases (Table 1.2). The installation of floating offshore wind platforms entails less interference with the seabed. Innovations in ships' ballast water treatment are expected to make a significant contribution to reducing the spread of alien marine species. The conversion of rigs and renewable energy infrastructure to reefs may lead to restoration of fish and mollusc stocks, to reduction in disturbance of the seabed and in destruction of benthic fauna and flora, although the conditions under which these benefits may occur are yet to be fully understood. In some circumstances, they may enhance the network of hard substrate ecosystems for certain species by acting as bridges (via larval dispersion) between otherwise distinct networks, be they in the deep sea, in fjords or in marine-protected coral areas (Henry et al., 2017[7]).

Table 1.2. Potential benefits to marine ecosystems may be significant, but are hard to quantify

Area of innovation activity	Examples of potential direct benefits to marine ecosystems	Examples of potential indirect benefits to marine ecosystems
Floating offshore wind farms	Less interference with seabed, as compared to traditional offshore wind farms	Possible contribution to slower growth in greenhouse gas (GHG) emissions from energy systems.
Progress in ballast water treatment in ships	Reduction in spread of (alien) marine species and in the use of chemicals	Lower levels of bio-fouling leading to lower fuel consumption
Advances in marine aquaculture	Reduction in coastal water pollution, in use of wild fish stocks for feed/ cleaning, and in use of antimicrobial treatments	Reduction in CO_2 emissions from lower energy consumption due to automation, remote monitoring etc.
Rigs and renewable energy platforms-to-reefs	Reduction in damage to seabed and benthic fauna and flora; enhancement or restoration of fish/mollusk stocks and hard substrate ecosystem networks	Reduction in GHG emissions from reduced dismantling of platforms and transport to and from port

In the case of scientific and technological advances in marine aquaculture with respect to site selection, breeding, feed, waste treatment, and disease control and treatment, all would appear to benefit on balance the sustainability of coastal ecosystems. These benefits could potentially be overshadowed by the engineering solutions that increase the likelihood of moving aquaculture offshore. Open-ocean aquaculture appears to offer many advantages compared to coastal seafood farming: fewer spatial constraints; less environmental impact; lower risk of conflicts with other ocean users; and, fewer problems with disease. However, very few large-scale open-ocean farms are currently in operation, not least because they face a host of challenges: designing structures that can withstand the harsh conditions of the open ocean; access to the facility for monitoring, harvesting and maintenance purposes; communications; and safety of personnel, to name but a few. Yet recent studies suggest the potential area for ocean aquaculture is large. Indeed, it could theoretically encompass an area of over 11 million km^2 for finfish and over 1.5 million km^2 for bivalves – sufficient to grow 15 billion tonnes of finfish a year, or 100 times the current global levels of seafood consumption (Gentry et al., 2017[8]).

Indirect benefits to the environment are thought to be substantial in the case of floating offshore wind energy, given its potential to reduce global CO_2 emissions. Estimates of carbon emissions from offshore wind generation conducted in 2015 place life-cycle emissions in the range of 7 to 23 grams of CO_2 equivalent per kilowatt (gCO2e/kWh). This compares with around 500 grams for gas-fired conventional generation and about 1000 grams for coal-fired conventional generation (Thomson and Harrison, 2015[9]). The potential decline in CO_2 output, in turn, stands to benefit the world's marine ecosystems by contributing indirectly to a reduction in acidification, de-oxygenation and the rise of sea temperature and sea levels.

Future development may be constrained by gaps in scientific knowledge

Although some evidence points to possible positive impacts on the economy and ecosystems alike, many crucial questions remain to be answered in terms of the potential effects of many of the above-described innovations, which may hamper or at least slow their application on a larger scale.

Table 1.3. Limited scientific knowledge of the potential impacts on marine ecosystems could prove a constraint for some sectors

Area of innovation activity	Examples of knowledge gaps
Floating offshore wind farms	Too few floating platforms in operation for evidence-gathering, but need to study potential impacts of large-scale operations on (migrating) bird life, fish and marine mammals, as well as on seabed and benthic habitats due for example to wide ecological footprint of some mooring systems.
Progress in ballast water treatment in ships	Issues surrounding practical implementation of on-board ballast water treatment and efficacy of currently available technologies in different marine environments.
Advances in marine aquaculture	Few open ocean farming projects currently in operation globally due to considerable technical hurdles. Data on ecosystem impact weak and concerns surround operations at very large scale.
Rigs and renewable energy platforms-to-reefs	Risk of chemical pollution from infrastructure left in place. Some studies available on effects on fish populations (the "stock enhancement" versus "attraction" debate) but little thorough-going research into other ecosystem effects (bio-diversity, benthic habitats etc.) especially at deep-sea sites.

A big question around open-ocean aquaculture concerns the area-wide impact of the activity in the form of intensive, high-volume operations, and the implications for ocean carrying capacity. Data on this scale of ecosystem impact is very limited, making it particularly challenging to set a baseline of ecologically meaningful reference points such as minimum distance, depth, and current velocity.

With very few floating wind platforms as yet in operation at commercial scale, gaps remain in knowledge about the potential drawbacks for the marine environment. These include the impact on (migrating) bird life, the effects on fish and marine mammals, as well as those on the seabed and benthic habitats. And questions remain about ballast water treatment. These range from fundamental issues surrounding our understanding of how aquatic species spread through our ocean and seas, to concerns about the efficiency of various ballast water treatment technologies in different marine environments. For example, common and abundant seawater phytoplankton have frequently been found to be resistant to UV treatment, and especially smaller organisms and microbes often survive. And electro-chlorination has been found to demonstrate lower disinfection efficiency in upper reaches of estuaries and freshwater surroundings because of their lower salinity (Batista et al., 2017[10]).

Finally, conversion of rigs to reefs is a controversial issue, largely because of environmental considerations at the decommissioning stage. The United States has been implementing numerous rig-to-reef conversions for some years now, through dedicated rig-to-reef programmes. However, these are much less common elsewhere. Many countries have regulations that require complete or almost complete removal of offshore oil and gas infrastructures and subsequent clean-up of the seabed by the operator. Such regulations are motivated by concern that infrastructures left in place may pollute the marine environment through oil leaks or through chemical contamination, and that current generations have a duty to leave as clean an environment as possible for future generations. Recently, however, a growing debate has emerged among marine scientists and conservationists about whether a more flexible approach to decommissioning should be considered which leaves some of the lower infrastructure of some platforms in place. Several arguments are put forward in favour of partial as opposed to full removal of infrastructure. First, complete removal risks disturbing or destroying valuable habitats and biodiversity hotspots that have grown around and on the infrastructures, and in some cases disrupting the functioning of surrounding interconnected natural ecosystems. Second, complete removal may also lead to pollution by releasing trapped chemicals from the seafloor and/or disturbing toxic drilling waste on the seabed. Third, full removal is likely to generate much noise and disturb marine life in the area. And finally, complete removal of infrastructure may entail opening up previously classified no-fishing zones for fishing activity.

Strategic policy decisions and collective actions on this topic need to be founded on the best possible scientific evidence with respect both to the environmental issues surrounding the debate of partial versus complete removal of infrastructures, and to the question of the successful creation and long-term viability of artificial reefs. As this OECD study has endeavoured to show, much work is still required to deliver that evidence. Given the high stakes and the uncertainties and lack of knowledge around each of the options, much scientific work remains to be done (Fowler et al., 2018[11]).

1.2.3. Next steps

In conclusion, realising the full potential of innovations in the ocean economy will demand major efforts in science and technology research, on both sides of the equation: in achieving the breakthroughs that are required to exploit sustainably the rich opportunities now emerging for ocean-based industries, and in addressing the many vital knowledge gaps about the ocean environment which may act as impediments to the ocean economy's future development.

Two issues illustrate possible directions of future action, so as to balance the activities of ocean-based industry with careful management of the ocean environment:

- In terms of opportunities for innovators, decision makers seeking to encourage and support the development of innovations and their application in the ocean economy should not miss the potential economic benefits that could flow to upstream and downstream segments of the sector in question, or indeed spillovers in economic activity and technological progress outside of the sector in question. This would entail up-to-date and regular industry mapping, as to keep track of the growing synergies between sectors.
- And in environmental terms, increasingly significant areas for scientific research will concern the complex impacts on marine ecosystems stemming from the expected growth of ocean economic activity, in combination with the increasing

effects of climate change. The need to address major scientific gaps, via a co-ordination of public and private actors, will often have to take precedence before launching into major developments, so as to follow a precautionary approach and avoid damaging the ocean environment dramatically.

1.3. Seek ways to nourish the vitality of ocean economy innovation networks

As developments in many other sectors of the economy illustrate, successful innovation in science and technology often requires fresh thinking in the organisation and structure of the research process itself. And so it is with ocean-related research, development and innovation. Chapter 3 of this report focuses on a particular type of collaboration among marine and maritime actors: innovation networks in the ocean economy.

1.3.1. Features of ocean economy innovation networks

For decades, marine and maritime actors have been working together via industry clusters, joint research programmes and various knowledge networks. In recognition of these efforts, the OECD has begun to explore ocean economy innovation networks. They are initiatives that strive to bring together a diversity of players – public research institutes, small and medium sized enterprises (SMEs), large enterprises, universities, other public agencies – to work on a range of scientific and technological innovations in many different sectors of the ocean economy (e.g. marine robots and autonomous vehicles; aquaculture; marine renewable energy; biotechnologies; offshore oil and gas). Such networks respond to changes in the national and international research environment and leverage their diversity to the benefit of the ocean economy and, potentially, society more broadly.

Innovation networks in the ocean economy take numerous forms, from loose relationships between various independent actors to relatively formalised associations or consortia pursuing common goals. They also involve multiple types of organisations. Effective collaboration is therefore a central feature in the success of such innovation networks.

Innovation networks often involve many different types of organisations. Universities can play a significant role both as a source of basic knowledge and as potential partners for industry (OECD, 2008[12]). The inclusion of small and medium sized firms and entrepreneurs in ocean economy innovation networks is also often seen as a priority, as they can be not only beneficiaries of potential spillovers from larger knowledge-intensive firms but are also sources of new ideas and inventions for the other network partners (Karlsson and Warda, 2014[13]). Collaboration in this regard is often an important source of innovative knowledge for large firms, which are two to three times more likely to collaborate with public research organisations than SMEs (OECD, 2017[14]). SMEs, on the other hand, tend to collaborate more with their suppliers.

Publicly funded organisations often play a significant role in federating interested parties, channelling funds and facilitating common projects. Their role as both brokers and/or orchestrators of networked activity is a reason why the OECD has surveyed ten selected innovation networks with publicly (at least partially) funded organisations at their core (Table 1.4). Typically, innovation network centres conduct a number of important functions on behalf of the rest of the network, including designing membership, structure and position, and managing various aspects of the networks' activities (Dhanaraj and

Parkhe, 2006[15]). They also tend to facilitate access to research facilities, engage academia in industry and vice versa, and support small and medium sized enterprises.

Table 1.4. Innovation networks responding to OECD questionnaire

Innovation network centre name and country of origin

Name of innovation network	Country
Ocean Frontier Institute	Canada
Offshoreenergy.dk	Denmark
Innovative Business Network (IBN) – Offshore Energy	Belgium (Flanders)
Campus mondial de la mer	France
Marine Renewable Energy (MaREI)	Ireland
EXPOSED Aquaculture	Norway
MARE StartUp	Portugal
Scottish Aquaculture Innovation Centre	United Kingdom
Oceanic Platform of the Canary Islands (PLOCAN)	Spain
Marine Autonomous & Robotic Systems Innovation Centre	United Kingdom

Among the innovation networks surveyed, shepherding the innovation process across a diversity of actors remains a challenging endeavour. Some of the issues that were highlighted through the survey include orchestrating different types of organisations with sometimes competing priorities; balancing commercial potential and opportunities for more research; and, maintaining a culture of innovation among all participants in the network.

Activities of the surveyed innovation networks are broad, ranging from ocean monitoring to aquaculture to marine renewable energies. One interesting lesson learned from the survey is that innovation in the ocean economy is often no longer focused on developing a single new technology for a given sector, but on identifying smart combinations of existing and/or new ones to tackle complex problems. As seen already in the previous sections, sustainable growth of the ocean economy is likely to rely on technological advancements that are both multi-faceted within and across domains of expertise and reliant on numerous emerging and fast-changing enabling technologies. The types of technologies under development by the innovation networks in question include robotics, autonomous systems, wave and tidal technologies, new materials and structures, biotechnology and advanced marine sensors. Ocean economy innovation networks are one construction through which the synergies between such technological advancements and their uptake in ocean-based industry are being realised.

1.3.2. Well-run innovation networks generate a range of benefits for the ocean economy and beyond

Evaluating the performance of ocean economy innovation networks will be an important step in assessing the benefits associated with them. Independent and credible scrutiny is required to ensure that public funds reach their target of facilitating co-operation between different stakeholders and lead to innovations. Furthermore, evaluating the performance of innovation networks over time will help ensure their effectiveness and sustainability as they mature. Where independent assessments of ocean economy innovation networks have already been carried out, they have shown generally positive impacts within and beyond the sector under investigation. However, more efforts to assess impacts in more locations will be required if their value is to be fully assessed and widely understood.

The OECD survey suggests benefits are often generated in response to the challenges associated with increasingly multi-faceted research and development in the ocean economy:

- For example, a fragmentation in ocean research objectives and efforts is often observed among stakeholders (OECD, 2016[1]). In response, innovation networks provide a co-ordinated approach across disparate research communities and improve cross-sector synergies;
- A second challenge concerns the growing scientific, technological and logistical complexity of applied research in the ocean economy. A well organised innovation network brings together a diverse range of actors and partners and can strengthen multidisciplinary approaches and activities. It may also enable the exploration of opportunities for combining established and emerging technologies;
- The third challenge in this regard concerns exploiting the synergies between and across sectors.

In addition, the survey suggests ocean economy innovation networks may produce benefits that spill over to society more generally. Scientific capacity and knowledge may be increased in any number of ways. One potential avenue being actively pursued is more cost-effective ocean monitoring, as the ability to measure and observe the ocean is the cornerstone of ocean sciences. Advances in this area lead to greater scientific and societal understanding of the ocean. The exchange of knowledge between economic sectors beyond the ocean economy also offers opportunities for progress. Innovation networks therefore play an important role in tracking technological developments, considering possible ocean applications and communicating advances to their partner organisations. Finally, innovation specifically in networks has a major role to play in the realisation of a sustainable ocean economy in more intangible ways. Matching collaborators with complementary but different expertise is likely to result in development paths that are some combination of the objectives of all parties involved. For example, the independent involvement of marine scientists in ocean projects early on, to study and model possible environmental impacts, may result in better acceptability to society for some projects than products resulting from innovative efforts conducted by industry alone.

In areas where ocean economy innovation networks are likely to produce positive impacts, policymakers may wish to encourage their development through a number of potential policy steps.

1.3.3. Next steps

In view of the diversity of existing ocean economy innovation networks, there is no ‘one size fits all’ recommendation. However, policymakers and other decision takers looking to encourage ocean economy innovation networks may wish to consider the following options:

- Ensuring the performance of ocean economy innovation networks is assessed through timely evaluations will help to guide their activities as they mature and clarify their effectiveness in achieving innovation outcomes;
- Where appropriate, efforts could be made to ensure ocean regulations are orientated towards innovation by increasing their flexibility. Consulting ocean economy innovation networks during the regulation-making process – and this is

already the case for some of the surveyed networks – is likely to result in a clearer, more effective and innovation-friendly regulatory environment;

- Public funding of innovative activities is often available for early technology readiness levels (e.g. from fundamental research to early demonstration phases), but, at times for certain innovation activities, further support may be required in the latter stages of development, both in terms of facilitating access to finance and in accessing test facilities and demonstration sites;
- Finally, the types of innovations under development, particularly those concerning ocean monitoring, could have many uses beyond their scientific and commercial applications, and as such they may be tested and exploited as advanced new tools for ocean governance.

Given all of the above, a possible OECD research agenda for further analysing ocean economy innovation networks emerges. Although collaboration between diverse actors in the ocean economy has been taking place for many years, the networks surveyed by the OECD were established recently and are sure to be undergoing fast-paced changes, mirroring the rapid innovation occurring in the areas in which they operate. A follow-up work programme will examine more centres, in different parts of the world, with different set-ups and characteristics, and explore new lines of enquiry. Finally, a study of the roles of intellectual property policies and alternative sources of finance for SMEs seems particularly pertinent to the ocean economy.

1.4. Support pioneering initiatives to improve measurement of the ocean economy

The technological and organisational innovations described in the previous sections have the potential to contribute to the development of ocean-based economic activity and to the conservation and sustainable use of marine ecosystems. The balance between the two will be crucial for achieving greater sustainability of the ocean economy.

National policies towards science and research will play a crucial role in guiding and influencing business development and the conservation and sustainable use of marine ecosystems; moreover, they will be instrumental in matters of stewardship, regulation and management of our seas and ocean. To perform those multiple assignments effectively, policies need to be evidence-based. However, a long journey still lies ahead to gather the information, data, analysis and knowledge that is vital for decision making in the ocean economy at all levels, from local to global.

With the above in mind, Chapter 4 outlines three examples of areas in which major advances in economic measurement, methodology and monitoring could signify decisive breakthroughs in offering public authorities (but also many other stakeholders) the evidential support they require for markedly improved decision making. These are:

- Standardising approaches to measuring and valuing ocean industries, and integrating them into national accounting via satellite accounts;
- Measuring and valuing natural marine resources and ecosystem services, and exploring ways also to integrate them into national accounting frameworks;
- Better identifying and measuring the benefits of public investment in sustained ocean observation systems.

1.4.1. Measuring and monitoring ocean-based industries

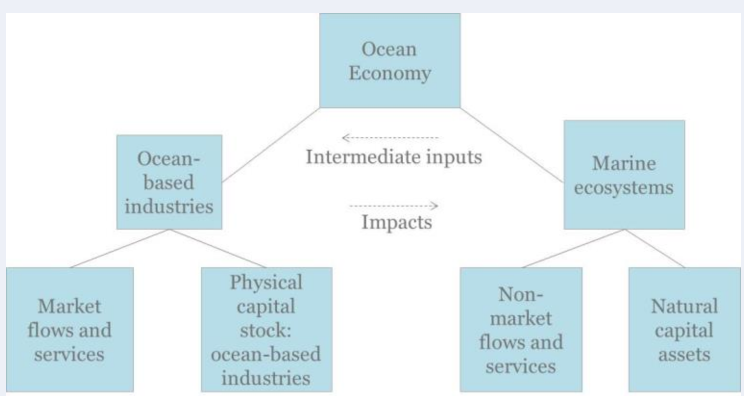
The importance of measuring the economic performance of ocean-based industry is becoming increasingly apparent to both public policymakers and private decision-makers alike. Many countries have in place data sets that attempt to measure and value their ocean industries. However, methods, definitions, classification systems and measurement approaches vary considerably over time and from country to country, making it hard for decision-makers to develop a consistent grasp of the value of ocean economic activity, track its contribution to the overall economy, and compare the size, structure and impacts of ocean economies internationally.

Despite the benefits associated with consistent ocean economy measurements, economic data has often been collected in an *ad hoc* manner. This has resulted in inconsistencies within measurements and a plethora of issues concerning comparability, both between the ocean-based industries that make up the ocean economy and between it and other sectors.

Box 1.2. Measuring the ocean economy's two pillars

The ocean economy is defined by the OECD as the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems (OECD, 2016[1]). These two pillars are interdependent, in that much activity associated with ocean-based industry is derived from marine ecosystems, while industrial activity often impacts marine ecosystems. The economic value associated with each pillar can be differentiated according to whether the goods and services that flow from it are traded in markets or not. This concept of the ocean economy as an interaction between two pillars with corresponding economic value is depicted in the figure below.

Figure 1.1. The concept of the ocean economy



Source: OECD (2016[1]), *The Ocean Economy in 2030.*

The interdependency of the two pillars, combined with increasingly severe threats to the health of the ocean, have led to a growing recognition that management of the ocean should be based on an integrated ecosystem approach (OECD, 2016[1]). Several management strategies have been suggested to achieve this, including Integrated Coastal Zone Management (ICZM), Marine Spatial Planning (MSP) and Marine Protected Areas (MPA). Crucial to each framework is accurate and extensive information base on ocean economic activity, the marine environment and the interactions between the two. Revealing the economic value of marine ecosystems aids this process. Robust measurements, in a common metric, are fundamental to ensuring ocean-based industries and marine ecosystems are managed in an integrated manner.

Many countries are beginning to commit resources to collecting more robust ocean economy data and efforts to collect data through national statistical systems are gaining momentum. Some, such as Portugal, have moved towards adopting satellite accounts for ocean-based industries that are compatible with the core national accounting system. Others have begun measuring ocean economic activity using methods similar to those used in satellite accounting. The Marine Institute of Ireland has collected economic data on an annual basis since 2004 and issues reports analysing key trends. Canada measures gross domestic product (GDP) and employment in several industries, while the EU Commission has collected similar data. Norway produces several publications detailing economic statistics in ocean-based industries, including tracking changes in natural resources. The Danish Maritime Authority monitors activity across a number of core and secondary industries of its maritime cluster. Italy has produced several metrics of its maritime economy, including value-added and employment. The Korea Maritime Institute has recently extended the scope of its ocean economy measurements to include marine services and resource development. An alternative approach has been adopted by the National Marine Data and Information Service of China, which uses ratios to disaggregate data on ocean-based industries from broader statistics.

Issues preventing consistent measurements of the ocean economy

Although efforts to collect robust information on the ocean economy are increasing, economic data currently collected through most countries' national statistical systems remains incompatible for two core reasons. First, data from official sources tend not to be disaggregated by the area of the economy on which it is focused. For example, activity in the oil and gas industry is often reported as an aggregation between offshore and onshore drilling. Second, it is sometimes difficult to define precisely which activities qualify as land-based and which count as ocean-based. Ports, for example, are land-based centres of much economic activity that would not exist were it not for the ocean.

Such issues are concerned primarily, but not only, with the difficulty of ensuring industrial classifications separate all ocean-based industries from their land-based counterparts. OECD research suggests that only three ocean-based industries appear in the UN Statistical Commission's International Standard Industrial Classification of all Economic Activities (ISIC) at the level of detail collected by most statistical administrations. This is considerably lower than the 19 ocean-based industries defined in *The Ocean Economy in 2030* (OECD, 2016[1]). If classifications for all ocean-based industries were to exist, then data appropriate for the entire ocean economy would be identifiable through the system of national accounts and made available by national statistical offices alongside comparable data on all other economic sectors.

Ocean economy satellite accounts offer a way forward

Presenting extensive ocean economic data through satellite accounts to the existing national accounting system provides a solution to such problems. Satellite accounts offer a robust framework for monitoring aspects of a country's economy not shown in detail in the core national accounts while allowing for greater flexibility for those industries not covered by industrial classifications. To maintain coherency, the basic concepts and accounting rules of the core national accounting system are adopted. However, important data otherwise missing from measurements of the total economy – such as data collected outside of the usual surveys used for the national accounts – can also be included, enabling full coverage of the ocean economy. Many national statistical systems already produce satellite accounts for a range of sectors – such as housing, health, social welfare, national defence, education, research and the environment – and accounts could conceivably be compiled for any sector in which there is sufficient interest. The creation of a satellite account for the ocean economy could be managed along the same lines as those already inaugurated, with an agency relevant to the ocean working alongside the statistical authority.

Next steps

Satellite accounts for the ocean economy would provide a highly organised method for collecting consistent ocean economy data. Should a critical mass of countries develop such accounts then international comparability would be enhanced. Given this, a framework is necessary for countries wishing to move towards satellite accounting for the ocean economy. The National Accounts Division of the OECD's Statistics and Data Directorate has developed guidance for sectoral experts wishing to pursue satellite accounts. The limitations described above suggest the international community is still some way from being able to formalise ocean economy satellite accounts.

There are, however, promising signs. As previously mentioned, many countries have begun collecting data on the ocean economy either directly or via industry-led surveys. Such studies represent a good first step in the development of future accounting measures. These efforts could continue to be supported – accumulating as much data as possible on the scope of the ocean economy within a country will provide a valuable baseline from which a more formal ocean satellite account can be built. International efforts will be aided considerably if the results and methodologies relied upon to do so are distributed openly and widely.

The process of developing a satellite account for all ocean-based industries is almost certainly a process that requires expertise in the ocean economy and expertise in national accounts. Therefore, resources could also be committed for ocean economy specialists to work alongside national accountants to lay the foundations for experimental satellite accounts in interested countries. In parallel, there are additional steps that could be taken at the international level. Fundamentally, industrial classifications are required that capture all ocean-based activities and differentiate between land-based and ocean-based industries. Countries wishing to pursue internationally comparable measurements should continue to work on common basic definitions to aid the revision process in this regard.

1.4.2. Measuring and monitoring marine ecosystems

Measuring the value of marine ecosystems is a complex exercise, currently far more complicated than estimating the value of ocean-based industries. For this reason, many estimations of the value of the ocean economy quantify only ocean-based industries and leave the value of marine ecosystems services to be discussed mainly in qualitative terms. This approach, however, does not enable the interactions of both pillars of the ocean economy to be analysed in a robust manner. Several countries have therefore begun to quantify changes in marine ecosystem services at the national level. Norway, for example, uses information collected in the Nature Index of Norway to assess the general health of Norwegian marine ecosystems.

While such efforts are to be commended, they do not enable the assessment of ocean-based industries and marine ecosystems in a common metric. An important reason for expressing the value of marine ecosystems in monetary terms is the conversion of biophysical data on the marine environment into a form compatible with other economic measures – such as the monetary values used for ocean-based industries. Readily available estimations of the economic value of marine ecosystem services would reduce the costs associated with ensuring data recorded through economic transactions and typically non-monetary environmental information are comparable. The resulting data can then be fed into analysis that attempts to understand the impact of particular decisions on the marine environment.

Satellite accounts offer a way forward here too

An ocean economy satellite account could conceivably include accounts related to marine ecosystems. Although the core system of national accounts is designed for the measurement of economic activity (through key indicators such as GDP, value added and employment), the interdependency of ocean-based industry and marine ecosystems imply the inclusion of environmental information is of particular importance. While ocean-based industry could be measured according to the core system of national accounts, comprehensive data on the value of marine ecosystems, both in physical and monetary units, can also be accounted for. There are examples of countries attempting to measure the value of ecosystem services in ways that are compatible with the national accounting system. The Marine Institute of Ireland, for example, has estimated the value of marine ecosystem services using definitions given in the European Environment Agency's (EEA) Common International Classification of Ecosystem Services (CICES). The Australian Bureau of Statistics has developed an experimental ecosystem account for the Great Barrier Reef. And Portugal has outlined its intention to include marine and coastal ecosystems services in its Satellite Account for the Sea.

In order to ensure satellite accounts containing environmental information meet the rigorous accounting standards of the system of national accounts, the international statistical community has developed further guidelines for accounting for environmental impacts, goods and services. The System of Environmental-Economic Accounting 2012 - Central Framework (SEEA Central Framework) is the internationally accepted standard for accounting for environmental stocks and flows (United Nations, 2012[16]). The System of Environmental-Economic Accounting – Experimental Ecosystem Accounting is a framework for accounting for ecosystem services, not yet accepted as an international standard due to its experimental status (United Nations, 2012[17]).

But accounting for marine ecosystem services remains a work-in-progress

Marine ecosystem accounting is in its infancy, with very few examples of established experimental accounts available. The accounts detailed in the SEEA Central Framework and Experimental Ecosystem Accounting are suitable for most terrestrial ecosystems and many freshwater bodies, but do not cover marine ecosystems particularly well. The classification system used in order to avoid double-counting between different types of ecosystem services may not be entirely suitable for marine ecosystem services and continues to be refined more broadly. Finally, most estimations of the value of marine ecosystem services are based on welfare measures. Such studies, while crucial to many types of policy analysis, are not suitable for ecosystem accounting that requires estimations based on exchange values.

Next steps

Much progress is needed before marine ecosystem accounts can be added to an ocean economy satellite account. The few examples of experimental accounts that do exist should be studied by any organisation looking to begin accounting for marine ecosystem services. As the knowledge base build ups on marine ecosystems, more efforts to share experiences internationally would greatly benefit the process of refining both the international accounting guidelines and ecosystem service classifications, as well as increasing awareness of the value of ecosystems to human wellbeing. In the meantime, valuations based on exchange values should be considered as an option for those wishing to make the transition to ocean accounts that include marine ecosystem services.

1.4.3. Measuring and monitoring the benefits of sustained ocean observation

The need to better understand the ocean, its dynamics, and its role in the global earth and climate system has led to the development of complex ocean observing systems at local, regional, national and international levels. These observing systems comprise fixed platforms, autonomous and drifting systems, submersible platforms, ships at sea, and remote observing systems such as satellites and aircraft, using increasingly efficient technologies and instruments to gather, store, transfer and process large volumes of ocean observation data. The data are crucial for many different scientific communities and for a wide range of public and commercial users active in the ocean economy.

The ultimate beneficiaries of ocean observations are end users whose activities or businesses benefit from ocean data and information in terms of better scientific understanding of the ocean, improved safety, economic efficiency gains or more effective regulation of ocean use and the protection of the ocean environment.

It is clear that the economic and societal benefits underpinned by ocean observations, measurements and forecasts are large. However, they are difficult to quantify. There have been no comprehensive global attempts to describe and quantify these benefits, although numerous case studies have sought to understand and quantify socioeconomic benefits associated with use of ocean data in support of specific ocean uses or regulatory measures. In aggregate, the cost of obtaining and using ocean observations is almost certainly only a small percentage of the value of the benefits derived.

Tracking the benefits of ocean observations

Recent work by the OECD has sought to collate and summarise the existing literature concerning the benefits of sustained ocean observations. It provides a review of much of the existing literature concerned with the role and value of ocean observations in enabling and supporting the ocean economy.

Science remains a crucial driver for most ocean observations. Observations and measurements derived from diverse platforms (e.g. in situ, research vessels, satellite remote sensing) contribute to advancing fundamental knowledge on the ocean, weather and the climate, directly and via their use in driving, calibrating and verifying ocean, atmospheric and climate models. In the Intergovernmental Oceanographic Commission's (IOC) Global Ocean Science Report, around 80% of data centres that provide ocean observation data, products and services named scientific communities as their most important end users (IOC, 2017[18]).

Many of the social benefits associated with improved science are not readily associated with economic value, partly because they do not flow through markets and do not generate economic benefits in and of themselves. For this reason, the literature has often considered ocean observation data to be a public good, the benefits of which are difficult to identify and value. Despite the relative complexity of valuing social benefits, a number of recent studies have used a range of methodologies to do so. Further valuation of social benefits is of particular importance to undertaking a thorough assessment of the value of ocean observing systems and is of crucial importance to any future overall economic assessment.

There is a wide diversity of operational products and services based on sustained ocean observations. Based on the OECD literature review, weather forecasts (36%), sea state forecasts (21%), and climate forecasts (7%) are the products and services most taken up for study. Some of the traditional operational user groups include navies and coastguards, offshore oil and gas industry, and commercial shipping fisheries and aquaculture. User domains benefiting from ocean observations and covered the most by the literature do not, paradoxically, mirror the distribution of these traditional user groups. This is because much of the work on quantifying these areas exists only in the 'grey' literature rather than as peer-reviewed material. The socio-economic assessments consider primarily aquaculture and fisheries (13%); agriculture (9%); environmental management (8%); tourism and cruises (8%); pollution and oil spills (8%); military, search and rescue (8%); and commercial shipping and maritime transport (8%).

Benefits of publicly funded ocean observation systems recognised within the literature can be categorised according to three broad domains:

- Direct economic benefits are the revenues associated with the sale of information products derived in whole or in part from ocean observations, for example, the sale of sea surface temperature products used by the commercial and sport fishing industries to aid in the location of target fish species. This category is relatively straightforward, but the economic data needed to conduct the assessment are generally quite scarce.
- A second category comprises indirect economic benefits. These are accrued when an end user derives an indirect benefit from purchase of an information product or service resulting in whole or in part from ocean observations (e.g. better ship routes as a result of accurate weather forecasts, valued, for example, by reduced fuel costs as a result of avoiding bad weather). The indirect economic benefits follow gains in efficiency or productivity from using improved ocean observations. This category is the most represented in the literature with cost savings (30%), cost avoidance (15%) and increased revenues (14%) as the three most frequent types of benefits cited in the studies.
- Finally, societal benefits are received by society in general in ways that are often easier to identify than to quantify (e.g. improved ocean governance, environmental management or better understanding of the impacts of climate change valued, for example, by estimation of the avoided costs associated with mitigating climate change). The most frequent types of societal benefits are improved environmental management (10%), lives saved (7%) and improved forecasting (6%).

These different types of benefits can be assessed with qualitative or quantitative measures. While ongoing efforts are to be commended and recent progress has been made on mapping operational user communities, data on intermediate and end users are often not collected.

Next steps

A thorough assessment of the value of ocean observations requires further effort in identifying and understanding the different communities of intermediate and end-users, their use of ocean observations and the associated benefits. All based on common standards. Quantifying socio-economic benefits of ocean observing activity in the ocean economy will support arguments for maintaining and improving ocean observing systems.

Following on from the OECD's study on the socio-economic valuation of sustained ocean observations, the following steps could contribute to achieving this:

- Increased efforts among providers of ocean observations to track user groups, downloads and use of data, would help identify associated marketable and social values. This would involve improved identification and mapping of end users, both scientific and/or operational. Dedicated surveys of end users of ocean observations could be a useful tool to further characterise users, the products and services they require, and the benefits they realise by using ocean observations. These surveys could be conducted in co-operation with open data platforms, such as the Australian Open Data Network, the Copernicus Marine Environmental Monitoring Service (CMEMS), the European Marine Observation and Data Network (EMODnet) or the U.S. Integrated Ocean Observing System (U.S. IOOS), with their user bases as the target survey groups. CMEMS already gathers some of this information through its user registration process.
- A more thorough and detailed analysis of dedicated value chains for some of the main products and services derived from ocean observations could also contribute to a more robust valuation of socio-economic benefits. There are useful efforts underway at international and national levels, e.g. work by IOC, the National Oceanic and Atmospheric Administration (NOAA) in the US and under the European AtlantOS project, as well as a recently commenced project being undertaken by US IOOS Regional Associations to survey their users. Convening an expert meeting specifically on lessons learnt from mapping user groups' value chains would be very useful for the ocean observing community.
- Studies differ considerably in spatial and temporal scope, methodology used, and user domain considered. The ocean observation community would benefit from international standards or guidelines for the valuation of ocean observations. This would simplify the comparison of different studies and allow the aggregation of results. There are several general challenges when assessing the benefits of ocean observations, e.g. the public good character of many ocean observations, complex value chains and taking stock of a variety of stakeholders. Comparing the results of individual studies can be complicated by varying temporal, sectoral and spatial scales applied in the assessments. Improvements in methodologies are, however, possible. The weather and the environmental policy communities have both tested and paved the way for useful and proven value of information techniques that may be applicable to ocean observations.

In conclusion, recent years have seen a rapidly growing awareness worldwide of the importance of our seas and ocean as a key natural resource and engine of economic growth. Harnessing and simultaneously safeguarding the ocean economy will require deeper scientific knowledge, and more data than are currently available.

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