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Value Chains in Public Marine Data: A UK Case Study

A joint OECD Working Paper in collaboration with the UK Marine Environmental Data and Information Network (MEDIN) and the Global Ocean Observing System (GOOS) in the Intergovernmental Oceanographic Commission of UNESCO

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Marine data play a crucial role for many scientific disciplines, as well as for very diverse operational services such as fisheries management, environmental planning, marine conservation, weather forecasting, or port management. The information derived from marine data is also increasingly finding its way into a wide and varied range of public policy arenas and private industries. Collecting, distributing and archiving public marine data provide benefits to society at large, however as with all public investments, assessments are needed to provide evidence to decision makers. Based on an original survey of UK marine data users, this paper explores pathways through which marine data are used and transformed into actionable information, creating systematised value chains for the first time. The analysis unveils trends in current marine data uses in the UK and key benefits of data uses. The paper lays the foundations for further OECD work with the marine data community.

Keywords: Science and Technology; Digital; Economy;Green Growth and Sustainable Development

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Foreword

Marine data play a crucial role for many scientific disciplines, as well as for very diverse operational services such as fisheries management, environmental planning, marine conservation, weather forecasting, or port management. The information derived from marine data is also increasingly finding its way into a wide and varied range of public policy arenas and private industries. It is supporting commercial activities on a day-to-day basis, and in many cases bringing productivity gains, new cost efficiencies and opportunities for cost avoidance. These benefits could be augmented through appropriate public sector support. But policy-makers often lack the evidence base to guide and prioritise the additional efforts and investments required. What is needed is improved knowledge and understanding of the benefits of marine data and their socio-economic value.

Over the years, various assessments have been conducted of the costs and benefits of collecting and distributing marine data for ocean research and operational purposes. And a number of dedicated surveys have been developed, targeting industry users of marine data in some specific sectors to estimate the value derived from initial observations. But as yet, little evidence has been collected about the uses of marine data made available in public data repositories, or the specific value chains involved in those uses.

This paper represents a step towards remedying that situation. It is the product of close collaboration between the Ocean Economy Group of the OECD's Directorate for Science, Technology and Innovation (OECD STI Ocean Economy Group), the UK's Marine Environmental Data and Information Network (MEDIN) and the Global Ocean Observing System (GOOS), which is sponsored by the Intergovernmental Oceanographic Commission of UNESCO, the World Meteorological Organisation, the United Nations Environment Program, and International Science Council. To help close some of the gaps in our knowledge about public marine data users, a detailed survey was developed of the users of marine data repositories in the UK MEDIN network of data management centres – the Data Archive Centres (DACs). Several DACs kindly contributed to the exercise, reviewing the initial questions and highlighting the survey to their users.

The paper presents the results of this first national survey. It provides information on the spread of marine data usage in different sectors of the UK economy and beyond. Moreover, using systemised value chains, it maps how marine data flow from diverse fields of use (e.g. climate science, conservation) into actions actually taken (e.g. informing coastal planning decisions, managing marine resources). The key benefits of marine data use revealed by respondents are identified qualitatively, laying the foundations for further valuation exercises. The analysis also unveils some trends in current marine data uses in the UK.

As a follow up to this paper, OECD work with the ocean observing and marine data community will continue, both to develop further the detailed analysis of dedicated value chains at national and regional levels, and to strengthen the knowledge base on socio-economic methodologies for impact assessment. As the United Nations Ocean Decade for Ocean Science for sustainable development is just starting, with a strong push for partnerships and investments to sustain ocean research infrastructures, the objective is to contribute to a more robust valuation of the socio-economic benefits generated by crucial public marine observing and data infrastructure systems, to continue providing evidence to policy-makers.

Acknowledgements

This working paper is the result of close cooperation between experts from the OECD Ocean Economy Group of the OECD's Directorate of Science, Technology and Innovation (OECD STI Ocean Economy Group), the UK Marine Environmental Data and Information Network (MEDIN) and the Global Ocean Observing System (GOOS). The paper was designed, researched and drafted by Claire Jolly, head of Unit and James Jolliffe, economist and policy analyst at the OECD, Dr. Clare Postlethwaite, UK MEDIN Coordinator at the National Oceanography Centre, and Dr. Emma Heslop, GOOS Programme Specialist from the Intergovernmental Oceanographic Commission of UNESCO. James Jolliffe managed the online survey, cleaned the results, and produced the data visualisations in the paper.

Many organisations kindly contributed to this exercise.

- This case study on marine data valuation is part of the OECD programme of work on the ocean economy, which would not exist without the continued support, generous expertise and invaluable advice provided by the Steering Board of the OECD STI Ocean Economy Group including the following organisations: Department of Economy, Science and Innovation of Flanders (DESI), Belgium; Marine Institute, Ireland; Stazione Zoologica Anton Dohrn (SZAD), Italy; Korea Maritime Institute (KMI), Korea; Research Council of Norway (RCN), Norway; the Directorate-General for Maritime Policy (DGPM) and Foundation for Science and Technology (FCT), Portugal; and the National Oceanic and Atmospheric Administration (NOAA), United States. We warmly thank the steering board members and their experts in shaping the OECD programme of work on marine data and for their valuable comments on the drafts.
- MEDIN's partnering Data Archive Centres (DACs) were instrumental in this case study on UK marine data users, commenting on the initial marine data users' survey design and establishing connections with their user communities via their portals. Expert comments received on the draft paper were very welcome. We thank the following organisations who made this case study possible: the Archaeological Data Service (ADS); the Archive for Marine Species and Habitats Data (DASSH); the British Geological Survey (BGS); the British Oceanographic Data Centre (BODC); the Centre for Environment, Fisheries and Aquaculture Science (CEFAS); Historic Environment Scotland (HES); The Meteorological Office and the UK Hydrographic Office (UKHO). The UK Department for Environment, Food and Rural Affairs also kindly supported UK MEDIN for this exercise.
- The GOOS Office headquarters receives support from the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

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Executive Summary

The OECD supports countries to sustainably harness the opportunities of an increasingly digitalised global economy. Public marine data are a key resource for a knowledge-based ocean economy. Assessments of the costs and benefits of collecting, distributing and archiving the data are necessary to understand their value to society. Such evaluations provide decision makers with the evidence required to guide future investments.

This paper summarises the results of an original survey of users of data repositories in the United Kingdom's Marine Environmental Data and Information Network (MEDIN). It sheds new light on the various groups of users, the breadth of uses and reuses, and the benefits derived from marine observations and data management infrastructures.

The UK public marine data landscape is complex and evolving

- Marine observations generate raw data which can be stored in repositories commonly known as data archive centres (DACs). DACs give access to datasets, metadata and sometimes data-products. With dozens of expert DACs, the UK marine data landscape is diverse and complex. Public marine data are accessed via many different routes.
- Marine data users visit DACs for downloading raw datasets, running database searches to understand whether a particular need can be met by pre-existing data, and for accessing data products. The DACs therefore respond to a wide array of demands.
- The survey reveals the use of machine-to-machine connectivity. A notable share of survey respondents indicated they link to marine data through tools such as Application Programming Interfaces (APIs). This suggests DACs will have to remain current with the technological needs of their user bases.

UK public marine data value chains support diverse activities

- The flows of public marine data across various sectors of the ocean economy and their use for a range of actions in different fields were tracked using a systematised value chain approach.
- The occupations of UK marine data users vary but the majority of survey respondents were marine scientists. In terms of economic sectors, half of respondents work in academia and research centres, 21% work in the private sector, 12% provide consultancy services, and 9% work in industry. Just under 20% work in government/policy areas (including environment agencies and maritime authorities). The remainder work for non-governmental organisations and others. Among private sector respondents, there are specialised small and medium sized enterprises developing public marine data to create customised marine information products for commercial purposes.
- Respondents access a striking range of data types. The physical properties of the ocean influence many other aspects of the marine environment making physical oceanography a highly downloaded category (43% of data types used). Human activities data represent the second most used category (21%). The third highest

category of data types, biological oceanography (20.5%), are used in research but also in environmental and marine spatial assessments.

- Different groups use data for different purposes. In the commercial/industry sector, the main fields of use include marine science services (providing specialised services and commercial products to support scientists and public organisations), offshore wind, marine renewable energy, offshore oil and gas, and marine archaeology. Within this group, marine data serve to inform operations, but also contribute to spatial planning decisions and supporting risk analysis. In the offshore wind field, for example, the top actions for industry/commercial data users are to inform operations, analyse risk, validate data from other sources, and inform marine planning decisions.
- Marine data contributes to better knowledge and improved tools which generate various economic and societal benefits. These include revenues from the sale of marine information products *and* the productivity gains (i.e. cost savings and cost avoidances) derived from them. Other societal benefits highlighted include those related to environmental performance and improved ocean governance more generally.

Survey results based recommendations

… to institutional funders

- *Support the entire public marine data value chain:* Public marine data generate benefits in multiple economic and societal areas. Public agencies concerned with the development of marine observing and data management infrastructure should aim to support the continuous collection of public marine data and take advantage of new technologies that improve the efficiency of data storage and dissemination including through cloud technologies and APIs.
- *Use policy to promote the reuse of public marine data:* Policies that support specific ocean sectors, together with ad-hoc regulations and environmental assessment requirements, lead to reuses of public marine data beyond their initial purposes. Promoting the reuse of public marine data in relevant policies may also generate benefits beyond those currently considered. For example, impact assessments in the offshore wind industry increasingly require access to a new range of biological and environmental public marine data.

…to the marine observing community and data archive centres

- *Communicate the benefits of data use and reuse:* Many detailed and complex data value chains are revealed by the survey. Publicising use cases to different communities could encourage further unexpected uses. This 'broader than originally planned' data reuse is a key benefit of an integrated global ocean observing system, for example.
- *Better track marine data users:* Increased efforts to track user groups and their downloads would help identify and quantify the value generated from the data used without contravening the FAIR principles of data findability, accessibility, interoperability, and reusability. This would involve improved identification of data users through simple and, if need be, voluntary registration processes and via regular, voluntary surveys, for both regular and ad-hoc users. The value chain approach could be developed to inform dialogues with marine data users around their needs and requirements and aid communication with government on uses of marine observations.
- *Facilitate the use of APIs*: Account for the technical needs of data users and developers who can take advantage of technologies such as APIs to programmatically interact with marine data. This will enhance public marine data uses going forward. Furthermore, the observing community should focus on the importance of quality control, frictionless data flows, and metadata standards, all of which enable the seamless, programmatic reuse of marine datasets.

… on the next steps

The results of this survey provide much information on UK public marine data value chains. They contribute to broader efforts to value public marine data. Two next steps in this process could be:

- Assessing valuation methodologies for their suitability when applied to the specificities of public marine data reuse;
- Conducting surveys in different parts of the world to build an international knowledge base and improve understanding of value chains in different contexts and cultures to the benefit of all.

Acronyms

ADS	Archaeological Data Service (UK)
APIs	Application Programming Interfaces
BODC	British Oceanographic Data Centre
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CMEMS	Copernicus Marine Environment Monitoring Service
DASSH	The Archive for Marine Species and Habitats Data
EC	European Commission
EMODnet	European Marine Observation and Data Network
GDP	Gross Domestic Product
GOOS	Global Ocean Observing System
HE	Historic England
HES	Historic Environment Scotland
ICES	International Council for the Exploration of the Sea
IEEE SA	Institute of Electrical and Electronics Engineers Standards Association
FAIR	Principles of data findability, accessibility, interoperability, and reusability
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IOC / UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IOOS	Integrated Ocean Observing System
IMarEST	Institute of Marine Engineering, Science & Technology
IMBeR	Integrated Marine Biosphere Research
MASTS	Marine Alliance for Science and Technology for Scotland
NOAA	National Oceanic and Atmospheric Administration
NERC	Natural Environment Research Council
OBIS	Ocean Biodiversity Information System
OECD	Organisation for Economic Co-operation and Development
UK MEDIN	UK Marine Environmental Data and Information Network
UKHO	UK Hydrographic Office
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization

1. Introduction

1.1. Rationale and background

Marine data underpin a wide range of scientific research, and critically support the safe, effective and sustainable use of marine resources and conservation of a healthy marine environment (OECD, 2019[1]). Marine data are unique in space and time, but collecting them can be difficult and expensive (and sometimes even dangerous). As of early 2021, eighty-six countries are directly involved in marine data collection, with some 8 933 in situ ocean observing platforms, and 170 satellites continuously monitoring the global ocean and atmosphere (GOOS, 2021[2]).

In the larger context of publicly funded data infrastructure, public data and their reuse generate considerable social and economic benefits. It is estimated that data access and sharing produce benefits worth between 0.1% and 1.5% of gross domestic product (GDP) in the case of public-sector data, and between 1% and 2.5% of GDP (in a few studies up to 4% of GDP) when also including private-sector data. The estimated magnitude of the benefits depends on the scope of the data and the degree of openness/ availability (OECD, 2019[3]). Therefore, as with all public investments, a thorough assessment of the costs and benefits of collecting, distributing and archiving public marine data is useful to understand their value to society, and justify sustained publicly funded data infrastructure. Understanding this value is therefore a primary concern of policymakers and the global marine data and ocean observing communities.

As part of its mission to develop evidence on the ocean economy, the Organisation for Economic Co-operation and Development (OECD) held a first exploratory expert workshop in June 2016 in Kiel, Germany, on the challenges of valuing marine data. The workshop was organised in co-operation with the German Marine Research Consortium (KDM) and various stakeholders in ocean observation. As a second step, and in the framework of its project on the ocean economy and innovation, the OECD STI Ocean Economy Group, built upon its past work in co-operation with the Global Ocean Observing System (GOOS).

The OECD conducted an extensive and detailed literature review of over 90 papers written on ocean observation valuation. The analysis and original results were discussed at a workshop in Paris in May 2018, which revealed the extent of current knowledge and gaps on the economics of ocean observations. A summary of these findings was published in the report "Rethinking Innovation for a Sustainable Ocean Economy", which set out proposals for fresh approaches to closing the knowledge gaps (OECD, 2019[1]). Proposed solutions included improved tracking of marine data users (both scientific and operational), mapping value chains, and improvements to methodologies through the development of international standards or guidelines for the valuation of ocean observations. A new OECD programme of work was launched in 2020 supported by the OECD STI Ocean Economy Group’s Steering Board (see members in the acknowledgement section). This paper is one of the outputs of that activity.

The OECD programme of work on marine data benefitted notably from the momentum generated by the once-in-decade OceanObs’19 conference, as well as from the recommendations it produced. The conference gathered together more than 3 000 scientists, public and private practitioners and funders of observing systems to discuss the achievements and developments to come in ocean observations in the coming decade (Speich et al., 2019[4]). The need to foster transdisciplinary research was encouraged, particularly the active cooperation between the different ocean scientific communities, economists and social scientists, to study and communicate the value of marine data observations to society, and foster sustainable public marine data infrastructure (OceanObs19, 2020[5]).

The ongoing OECD research focuses on the detailed mapping of value chains as they relate to public marine data repositories, and on methodologies and possible future guidelines for the valuation of ocean observations. The OECD teamed up with the GOOS, and entered into a fruitful cooperation with the UK Marine Environmental Data and Information Network (MEDIN), to build a first case study on UK public data repositories' users and value chains. GOOS has strong interest in understanding value chains, in order to connect the value of the ocean observing infrastructure with the varied end use of the information collected, and also to support sustained and targeted investment in the global ocean observing system. As part of its *Global Ocean Observing System 2030 Strategy*, one of GOOS key objectives is to make connection down the value chain to ensure that ocean information, collected through the networks and organisations it coordinates, reaches many end users. Part of these connections is through key aggregating data centres and portals such as MEDIN.

Exploring detailed mapping of marine data value chains is the subject of this paper. Further work is ongoing on valuation methodologies, and future case studies are already planned with a view to developing and extending the evidence base to cover different types of value chains in different countries.

1.2. Novelty of the analysis

Over the years, various assessments have been carried out of the economic costs and benefits related to the collection and distribution of marine data for ocean research and operational purposes (e.g. OECD (2019[1]), Rayner, Jolly and Gouldman (2019[6]), Weller et al. (2019[7]), Commonwealth of Australia (2019[8]), Metz et al. (2018[9]), Cristini et al. (2016[10]), Kite-Powell, Colgan and Weiher (2008[11]), WAGOOS and AATSE (2006[12])). Some studies have been conducted to characterise businesses serving the ocean observing community and beyond, providing ocean measurement, observation and forecasting systems, but also the intermediaries using marine data to develop value-added products and services (Rayner, Gouldman and Willis, 2018[13]; ERISS Corporation, 2016[14]). Other initiatives include the new Benefits of Ocean Observing Catalog, supported by the US National Oceanic and Atmospheric Administration's Integrated Ocean Observing System (IOOS), and the GEO Blue Planet partnership which aims to raise awareness of the societal benefits of ocean observations. A recent position paper from the European Marine Board also highlights the benefits of in-situ ocean observations and their governance and funding challenges (European Marine Board, 2021[15]).

But as yet, not much evidence has been collected either about the use made of marine data available in public marine data repositories, or about the value chains involved in those uses. This paper and its findings constitute a first step towards remedying the situation, thanks to a cooperative effort between OECD and the UK Marine Environmental Data and Information Network, and to valuable inputs from GOOS.

To close the knowledge gap about users of specialised data repositories, a detailed survey was conducted of the users of marine data repositories in the UK MEDIN network of data management centres – the Data Archive Centres (DACs). Several DACs kindly contributed to the exercise, both by reviewing the initial questions and highlighting the survey to their users (see Box 1.1).

The paper provides new information on the spread of marine data usage in different sectors of the UK economy, based on the sample of respondents. It also uses systemised value chains to map how marine data flowing from diverse fields of use translates into actual actions. Key benefits of the marine data use are identified qualitatively, laying the foundations for further valuation exercises. But the findings also make apparent some important trends in current marine data uses in the United Kingdom:

- Evidence of a significant evolution in marine data access and management is captured by the survey: as databases become more interconnected and user friendly for a range of users, the growing importance emerges of users accessing data via Application Programming Interfaces or APIs, Web Map Services, or Web Feature Services.

- The importance of some relatively new industries as end-users of a wide diversity of marine data, including notably the offshore wind industry, is documented in the report.

Box 1.1. MEDIN data archive centres participating in the survey

- Archaeological Data Service (ADS)
- The Archive for Marine Species and Habitats Data (DASSH)
- British Geological Survey (BGS)
- British Oceanographic Data Centre (BODC)
- Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
- Historic Environment Scotland (HES)
- The Meteorological Office
- UK Hydrographic Office (UKHO)

1.3. The survey: purpose, response rate and sample characteristics

This paper presents the initial findings of the survey on the users of marine data from the UK Marine Environmental Data and Information Network (MEDIN) and a subset of its partnering Data Archive Centres (DACs) (the UK marine data management structure is detailed in Section 2).

This survey of marine data users had three objectives:

- Add to current understanding of the user communities who are globally accessing publicly available marine data in repositories;
- Explore the pathways through which marine data are used and transformed into actionable information;
- Lay the foundations for future work on measuring the value of publicly available data by creating selected systemised value chains of their use.

The survey was structured in such a way as to elicit information that could be used to map value chains, from the data management and archiving systems providing access to the data, to the users' characteristics (occupation, sector), their data needs, their actual selections of data, all the way to their initial data uses. Although only a sample of data repository users from MEDIN Data Archive Centres was surveyed, and not the full population of users, the results provide information on the variety of marine data users in the United Kingdom. They also provide information on the diversity of marine data usage in the sample of respondents, and use systemised value chains to illustrate how data flow from diverse fields of use to real actions.

The online survey comprising 17 sections of questions, was launched in late March 2020. The complete survey can be found in 5.4.Annex A. A link to the survey was placed on the UK's Marine Environmental Data and Information Network's homepage and on the portals of participating archive/management centres alongside a request to answer the questionnaire (see Box 1.1).

The questionnaire collected responses between March and early September 2020. In total, 191 respondents completed the survey. To put this number in context, MEDIN received 750 unique visitors per month between May and July 2020. During the same period, the participating data archive centres also received many unique visitors (e.g. DASSH 358 visitors, CEFAS 1105, BGS 2579, ADS 7086, and BODC 1053). On top of this, the data archive centres make their data holdings available via international infrastructure such as those provided by the International Council for the Exploration of the Sea, the Ocean Biodiversity Information System (OBIS) and others, thereby widening their user base further. The survey respondents provided detailed information, both qualitative and quantitative.

This paper is structured as follows:

- An overview of the marine data landscape in the United Kingdom, with a brief presentation of its data collection and distribution systems, its data policies and its linkages to the European and international data landscape;
- A review of the key findings from the UK survey of marine data users, following a value chain approach;
- Proposed next steps in valuation of the benefits coming from marine data, via further work on methodologies and a new set of case studies and surveys.

2. Overview of the marine data landscape in the United Kingdom

2.1. The UK marine data collection and distribution system

The United Kingdom has a long history of carrying out marine observations and making the data arising from those observations available for others to use. An early example of this is the systematic tidal measurements which were recorded in Liverpool in the 1760s and were used to produce the first reliable, publicly accessible tide tables. A few decades later in 1800, the first nautical charts were created and sold to the public by the UK Hydrographic Office. One of the longest time-series of phytoplankton and zooplankton in the world has been carried out by the Marine Biological Association from 1903 to this day. In all of these examples, the organisations, or their successors, remain active in making UK marine data accessible to others.

In the United Kingdom, responsibility for the environment is a devolved matter, which means that each country within the Kingdom (i.e. England, Scotland, Wales and Northern Ireland) has its own agencies with responsibility for collecting or managing marine environmental data for policy or regulatory purposes, adding to the already complex marine data landscape. There are currently over 600 organisations involved in collecting and/or managing marine environmental data in the United Kingdom. These include government departments and agencies; universities and other research institutes; commercial organisations and consultancies; charities and Non-Governmental Organisations as well as members of the public, participating in citizen science projects or similar.

The Marine Environmental Data and Information Network (MEDIN) was established in 2008 as a collaborative and open partnership to improve the management of and access to the UK's valuable marine data and information resources (UK MEDIN, 2021[16]). MEDIN holds and provides access to marine environmental data predominantly within UK territorial waters but further provides archiving and access to some marine environmental data collected by UK organisations on a global scale (Figure 2.1).

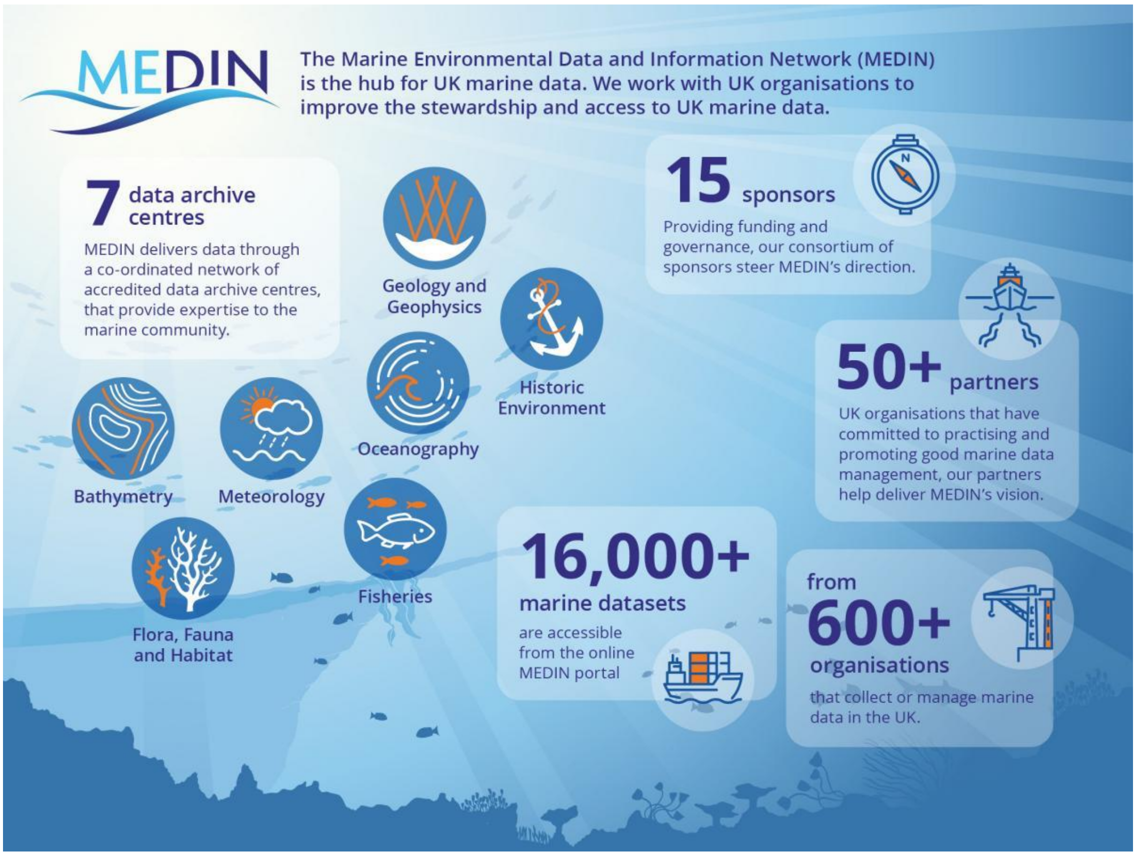
The MEDIN Data Archive Centres (DACs) provide the cornerstone for long-term management of UK marine data and are pivotal for delivering MEDIN's 'collect once, use many times' philosophy (see Box 1.1 with a list of DACs participating in the survey). The benefits of having a coordinated network of DACs and reusing data helps to avoid duplication of primary data gathering efforts, brings time savings through organisations not having to manage their own data (better formatting and storage), and contributes to the drive towards making data Findable, Accessible, Interoperable and Reusable (FAIR) (Wilkinson et al., 2016[17]).

MEDIN Data Archive Centres provide:

- Secure, long-term curation of key marine data sets, according to best practice and to relevant national and international standards.
- Clear, searchable information on their data holdings by the generation and publication of metadata on the MEDIN portal.
- Open and easy access to their data, wherever possible.
- The first point of call for expertise in the management of marine data.

The MEDIN DACs cover a wide spectrum of data within the marine environment, including bathymetry; fish and shellfish, fisheries, aquaculture and related samples; the historic environment; marine geology and geophysics; marine species and habitats; marine meteorology; and water column oceanography. The MEDIN DACs have adopted MEDIN's internationally compliant metadata standard and make their marine data holdings findable and accessible from the MEDIN portal. Widespread adoption of the metadata standard ensures all relevant information about a dataset is readily available to allow a potential user to make an informed decision about whether a dataset meets their needs. Complete and accurate metadata is key to making data reusable.

Figure 2.1. The UK Marine Environmental Data and Information Network (MEDIN)

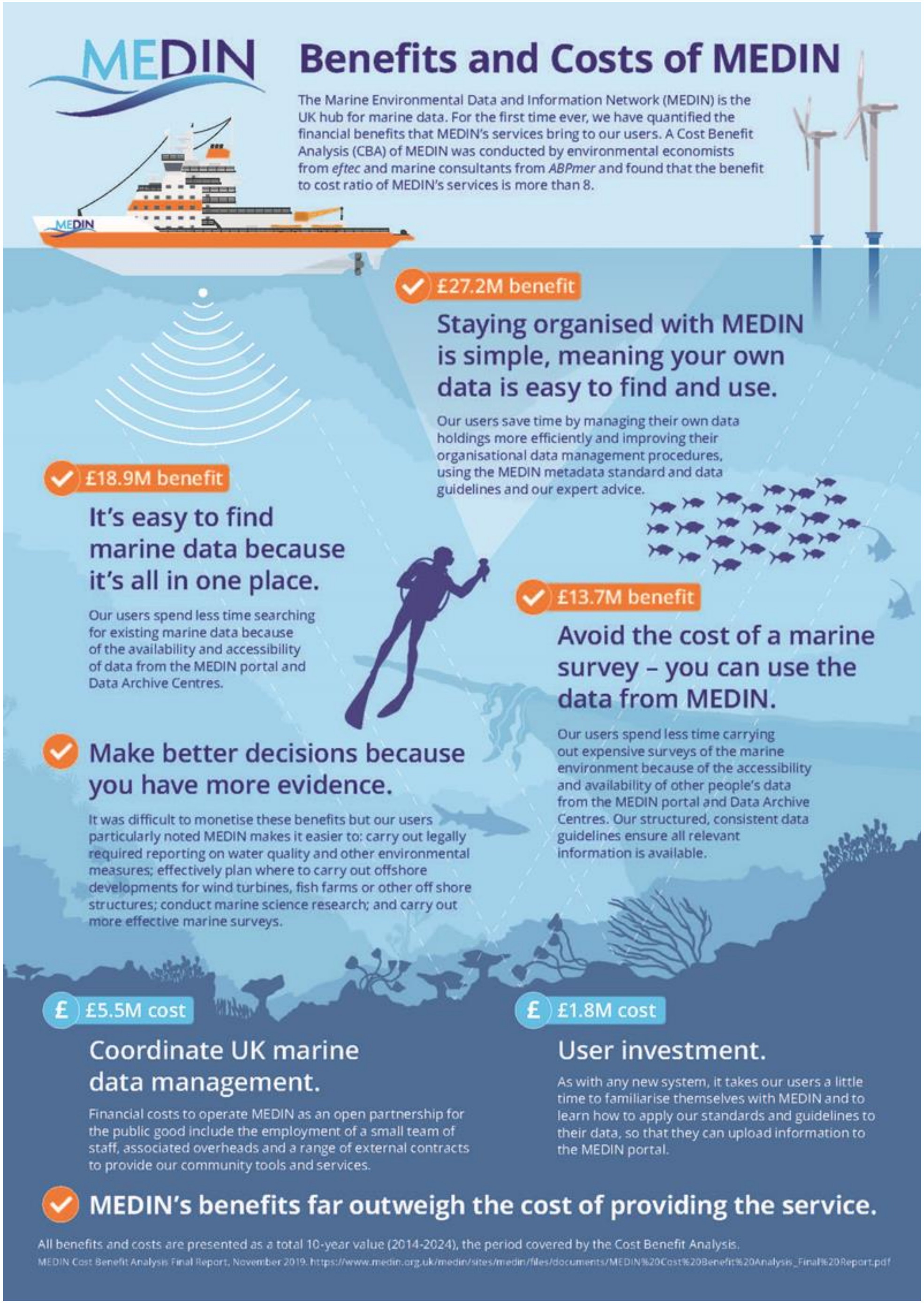


Source: UK MEDIN (2021[16]).

In 2019, MEDIN commissioned an independent cost benefit analysis to obtain robust quantitative and qualitative data around the benefits that MEDIN provides to its users through its portal and other services, comparing these against the financial and other costs associated with maintaining MEDIN (Figure 2.2). This was the first time that such analysis had been carried out and was an important step in quantifying the benefits of marine spatial data infrastructure, such as that provided by MEDIN. The study found that the benefit to cost ratio of MEDIN's services is more than 8:1 (Kuyer et al., 2019[18]), with improvements to organisational data management procedures identified as the biggest efficiency. Having a coordinated means to find and access marine data was also highlighted as a significant cost saving to users. More difficult to quantify, but nonetheless important, were the benefits that users found from making better, more informed decisions.

The cost benefit analysis of MEDIN specifically focused on the coordinated framework that MEDIN provides for the UK marine community and did not explore the value of the marine data itself. This gap in our understanding –the value of the data made accessible from public data repositories— is one focus of the work reported here.

Figure 2.2. Benefits and Costs of UK MEDIN



Source: UK MEDIN (2020), https://www.medin.org.uk/sites/medin/files/documents/Medin_infographic_A4.pdf

2.2. UK data access policies

The drive to make marine data openly and easily accessible has come from a variety of places: scientific rigour and curiosity; a desire to work offshore more efficiently and economically; and a growing need to sustainably exploit marine resources, such as food, energy and raw materials. However, the major driver in making marine or coastal data more easily accessible has historically been out of a concern for public safety, with supporting instruments such as the International Convention for the Safety of Life at Sea (SOLAS).

However, it was the European Union's INSPIRE directive (2007) which placed *legal obligations* on public bodies to publish geospatial datasets, to specified metadata and data standards. Putting this standardisation and requirement for open access into law was a step change for many UK public bodies. It is this combined with *environmental* legislation bodies (e.g. EU Water Framework Directive, European Marine Strategy Framework Directive, Birds Directive, etc.), that has played a significant role in driving easier access to UK marine environmental data from public repositories.

It is worth noting that some public bodies had been making marine environmental data openly available for much longer. For example, the Natural Environment Research Council (NERC), a key funder of marine scientific research, stipulates that data that it funds the collection of, is made openly available via one of its data centres. This data policy has been in place for over 25 years and built on good practices that were already in use.

Linking with emerging ocean economy sectors, the United Kingdom is a leader in offshore wind across Europe with long-term growth remaining strong, underpinned by a combination of drivers, including the UK's legal commitment to net zero emissions by 2050. The volume and variety of marine environmental data collected by the offshore wind sector is significant. Since the first UK offshore wind farm was commissioned in 2000, there has been a huge collective effort, led by The Crown Estate, to ensure that these data are easily available. The Crown Estate adjusted the data clause in their lease agreement in 2013 to stipulate that data must comply with MEDIN standards, thereby increasing the findability and (re)usability of the data. The Crown Estate data clause for the offshore wind sector has led to a step change in the availability of marine data collected by commercial organisations.

2.3. Linkages with the international ocean observing and marine data management landscape

The UK data management and archive centres are connected with an expanding network of regional and global marine observing communities. These communities are active in different disciplines and countries, and range from very small groups of individual researchers to thousands engaged together in large observing networks.

The Global Ocean Observing System (GOOS) has been leading the development of a truly global ocean observing system since 1991, and coordinates sustained ocean observing activities with almost a hundred countries to deliver essential information needed for sustainable development, safety, wellbeing and prosperity. It supports the development of harmonised data fit for users in three key areas: climate, weather and ocean prediction, and ocean health use. GOOS is led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and co-sponsored by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC).

The Global Ocean Observing System 2030 Strategy outlines 11 Strategic Objectives that guide GOOS in working towards a more coordinated, efficient and integrated system at international level that delivers data and information necessary for an increased range of users, across services, government and research. The strategy depends on partnerships, in particular with partners working down the value chain and connecting data to users. For example, a number of the data resources within MEDIN are collected by observing networks or regional systems coordinated by GOOS.

There are several key elements to the GOOS in situ observation coordination:

- The GOOS Steering Committee: a multinational body that provides direction to the GOOS core team in implementing its strategic objectives and building outside partnerships;
- The Observations Coordination Group (OCG) strengthens GOOS implementation by coordinating across 12 global observing networks, that collect a wide range of ocean and marine meteorological variables. The OceanOPS (i.e. the World Meteorological Organisation - Intergovernmental Oceanographic Commission Joint Centre for Oceanography and Marine Meteorology in situ Observations Programmes Support - formally known as JCOMMOPS) plays a core role in tracking timely exchange of data and metadata across the 12 networks, and providing visualisations of the observing system. The recently released 5-Year Strategic Plan for OceanOPS (2021-2025) guides its development of core functionality to support the global observing system (GOOS, 2021[2]);
- Expert Panels: The Physics and Climate, Biochemistry and Biology and Ecosystems Panels are vital for identifying user needs and evaluating the system across different disciplines, key to this is working with Essential Ocean Variables (EOVs) across the panels;
- The Expert Team on Operational Ocean Forecast Systems (ETOOFS) guides initiatives to improve capacity, quality and interoperability of ocean model forecast products;
- GOOS Regional Alliances (GRAs): GRAs identify, enable and develop GOOS ocean monitoring and services to meet regional and national priorities;
- And the GOOS Office: The GOOS Office team works full time to enable the GOOS core to function, and to enable connection across the observing enterprise.

Through these components, GOOS supports a community encompassing all those playing a role in the observing system: international, regional, and national observing programs, governments, UN agencies, research organizations, and individual scientists. By working together on observing tools and technology, the free flow of data, information systems, forecasts, and scientific analysis, this global community can leverage the value of all these investments

In this context, the development of standards, services, and infrastructures for providing means of discovery, long term storage and access to valuable marine data resources is an important activity at international level. With the exponential growth of marine data catalogues and records around the world (e.g. 70 different catalogues for the polar oceans already in 2019), comprehensive data discovery is becoming more of a challenge for researchers (Tanhua et al., 2019[19]).

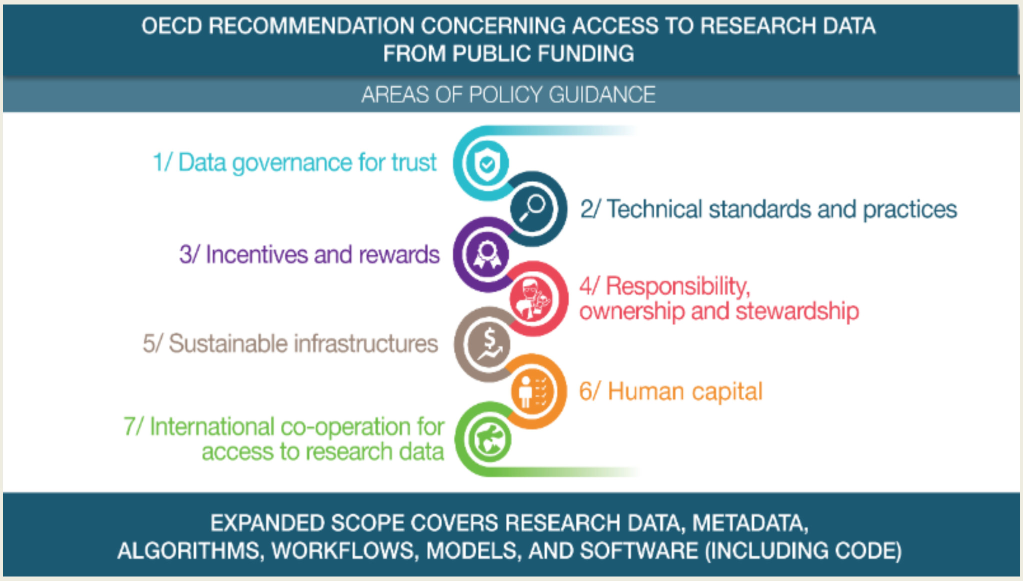
The adoption of the FAIR principles to facilitate data findability, accessibility, interoperability, and reusability for marine data is of utmost importance but remains quite challenging to establish in practice (Wilkinson et al., 2016[17]). A particularly important role can be played by governments and policy makers in enhancing access to and sharing data. The recently revised *OECD's Recommendation concerning Access to Research Data from Public Funding* adopted by forty countries in early 2021 aims to establish access and global sharing of research data as a major policy priority, with the ultimate goal of making the global science system more efficient and effective (OECD, 2021[20]). The revised Recommendation expands its scope to cover not only research data, but also related metadata (data about data, specifying their sources, methodology and limitations), as well as the bespoke algorithms, workflows, models and software (including code) that are essential for their interpretation. This may contribute to further enhancing access to and sharing of marine data (Box 2.1).

Box 2.1. OECD principles to enhance access to and sharing of data across the economy

The OECD contributes to the development of general principles for enhancing access to and sharing of data across the economy in a coherent manner. There are several OECD legal instruments that provide guidance and best practices on issues such as data openness, transparency, stakeholder engagement, intellectual property rights (IPR), and pricing. These legal instruments include:

- OECD (2006, updated in 2021) Recommendation of the Council concerning Access to Research Data from Public Funding
- OECD (2008) Recommendation of the Council for Enhanced Access and More Effective Use of Public Sector Information
- OECD (2014) Recommendation of the Council on Digital Government Strategies
- OECD (2016) Recommendation of the Council on Health Data Governance

For the *OECD Recommendation of the Council concerning Access to Research Data from Public Funding*, there are seven areas of policy guidance, summarised in the chart below.



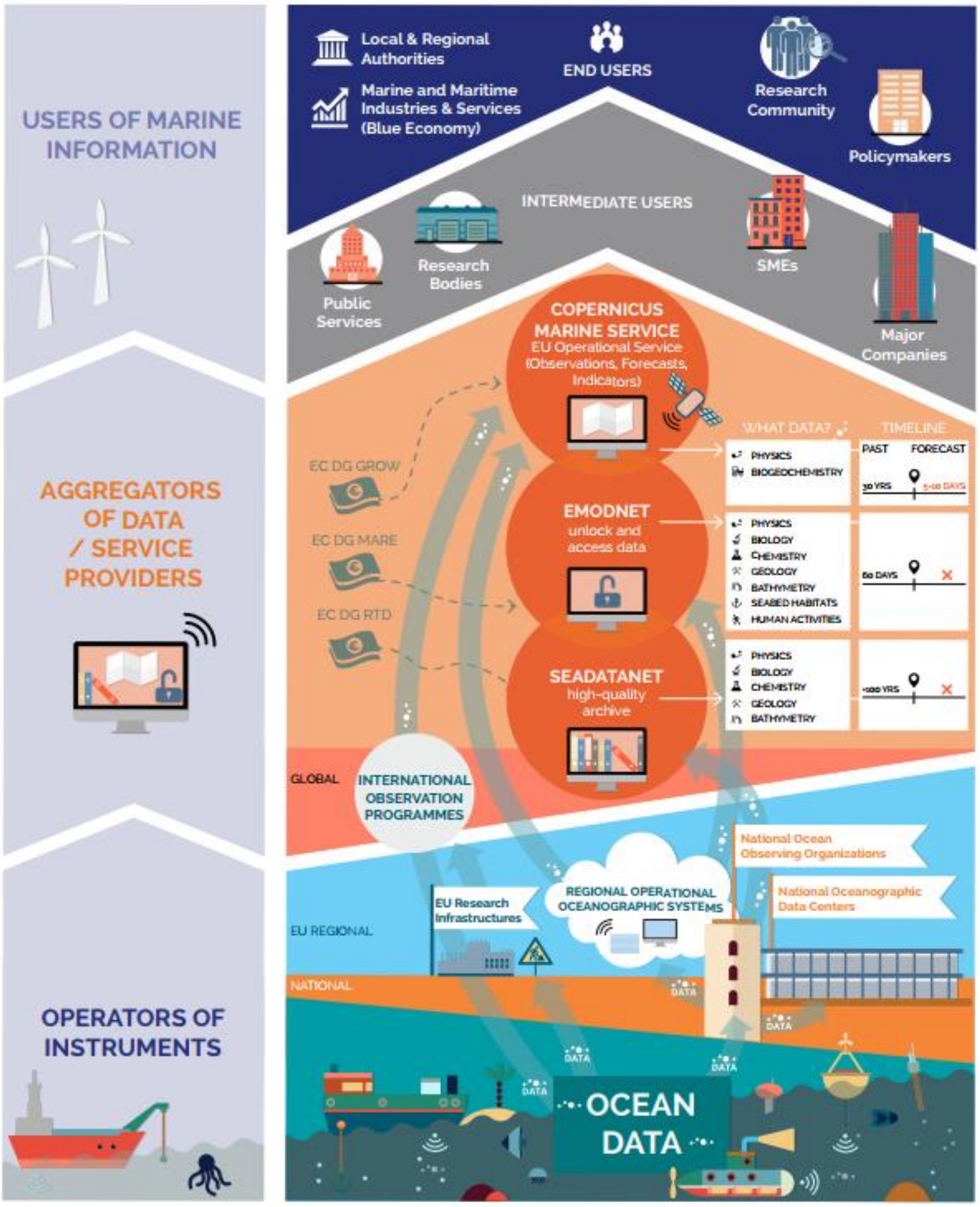
In the global marine data landscape, the International Ocean and Data Exchange (IODE) programme of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and the Data and Information Group of the International Council for the Exploration of the Sea (ICES) are active in development of standards, services, and infrastructures for providing means of data discovery. National and international experts meet regularly within the framework of IODE, ICES, and adapt the International Standards Organization (ISO), the Institute of Electrical and Electronics Engineers Standards Association (IEEE SA) and the Open Geospatial Consortium (OGC) standards, contributing notably to achieve compliance with the FAIR principles (and the Infrastructure for Spatial Information in Europe or INSPIRE at European level).

With specific regard to the European landscape in which UK MEDIN operates, marine data management and archiving relies on three main components which are SeaDataNet, EMODnet and Copernicus Marine Service (Figure 2.3). None of them operate observing platforms, but they assemble observations in cooperation and coordination with existing programmes and projects.

- SeaDataNet is a European Integrated Infrastructure Initiative connecting 110 data centres and making searchable more than 2 million oceanographic datasets acquired from research cruises and other observational activities in European and international waters (Pecci, Fichaut and Schaap, 2020[21]). Coordinated by IFREMER, its mission is to standardise, network and enhance the currently existing data infrastructures of 35 countries, operated by national oceanographic data centres and satellite data centres (SeaDataNet, 2021[22]). SeaDataNet develops important standards for data, metadata and vocabularies (some SeaDataNet vocabulary was used to draft the OECD marine data survey presented in this paper, see 5.4.Annex B for details of categories). It makes available a large collection of common vocabulary and standards online from different organisations, managed and hosted online by the British Oceanographic Data Centre. Building on these standards, SeaDataNet constitutes today a Pan-European network providing access to a Common Data Index service, which gives insight through a unique portal into the availability and geographical spreading of marine data sets from the connected data centres (in-situ data, meta-data and products). The datasets can then be accessed and downloaded from the different data centres, using increasingly the standard SeaDataNet data transport formats. More data centres from Europe are invited to connect so as to increase and expand the searchability of marine and ocean data sets for physics, biology, chemistry, marine litter, geology, geophysics, and bathymetry.

- The European Marine Observation and Data Network (EMODnet), an initiative of the European Commission in the context of its integrated maritime policy, manages a central portal to directly access and download marine data products from a large network of European organisations. Building on existing data repositories, infrastructures, initiatives and projects, it currently provides access to European marine data across seven discipline-based themes (bathymetry, geology, seabed habitats, chemistry, biology, physics, human activities) (Martín Míguez et al., 2019[23]). Users have access to standardised observations, indicators and processed data products, such as basin-scale maps (EMODnet, 2021[24]). EMODnet's expanding number of datasets is also powering largely the European Atlas of the Seas, which contains almost 300 maps as an educational tool. The Atlas is available in the 24 official languages of the European Union, allowing citizens to explore a wide range of popular marine topics, such as tourism, litter, environment, energy, and aquaculture (European Commission, 2021[25]).
- The Copernicus Marine Service (or Copernicus Marine Environment Monitoring Service or CMEMS) is the marine component of the Copernicus Programme of the European Union (Copernicus, 2021[26]). It provides free, regular and systematic information on the physical and biogeochemical ocean state, including sea ice, on a global and regional scale, using primarily satellite data and computer modelling. It is funded by the European Commission and implemented by Mercator Ocean International.

Figure 2.3. European landscape of marine data management



Source: Adapted from Copernicus (2021[26]).

3. Findings from the UK survey of marine data users

3.1. Introduction

The survey of marine data users from the UK's Marine Environmental Data and Information Network (MEDIN) and its partnering Data Archive Centres has been structured in such a way as to elicit primary information to help map value chains.

The survey follows the flow of marine data from the data management and archiving systems that provide access to the data, to the users' characteristics (occupation, sector), their data needs, their selection of data types, all the way to their initial data uses. The results provide first-hand information on the variety of marine data users in the United Kingdom. They also provide information on the spread of marine data usage in the sample of respondents, and use systemised value chains to show how data flow from diverse fields of use to actual actions. The key results are presented in the next sections.

3.2. Accessing data though data archive/management centres

Marine data archive/management centres store and archive large quantities of digital data, which must be managed, controlled, and made available for dissemination and use. In order to achieve this, data custodians record information about their data holdings in the form of metadata. Hence, data archive/management centres store data that are used for their original purpose, as well as to allow data discovery and reuse across different disciplines and sectors of the economy.

As a start, the survey respondents were asked which data archive/management centres directed them towards answering the survey. The results reveal the repositories that the respondents were visiting when answering, or the organisation that emailed them a link to the survey. The largest share of the respondents (31%) were visiting the Marine Environmental Data and Information Network (MEDIN), while some 17% were using the British Oceanographic Data Centre (BODC) portal. Other repositories included the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the UK Hydrographic Office (UKHO), the Archive for Marine Species and Habitats Data (DASSH), the Meteorological Office, the Archaeological Data Service (ADS), Historic England and Historic Environment Scotland (HES).

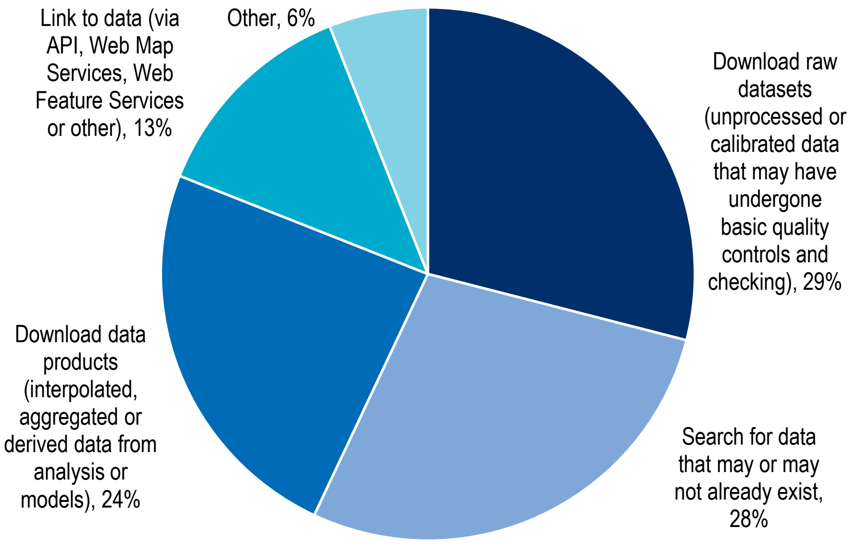
Around 25% of the respondents mentioned other routes (up to 20 different ones in total) by which they were directed to the survey (e.g. Marine Alliance for Science and Technology for Scotland (MASTS); National Oceanography Centre; the Global Ocean Observing System (GOOS) website; Institute of Marine Engineering, Science & Technology (IMarEST); Integrated Marine Biosphere Research (IMBeR); the Surface Ocean CO2 ATlas (SOCAT)). This demonstrates the wide variety and complexity of the marine data landscape in the United Kingdom.

Four main reasons for visiting a management/archive centre are identified in the survey. They include direct download of raw data, download of data products, browsing to find what data are available, and linking systems to existing datasets (Figure 3.1). Individual respondents could select multiple options. In terms of priorities, the responses are relatively evenly balanced among the first three aforementioned reasons:

- 29% mentioned they download raw datasets (unprocessed or calibrated data that may have undergone basic quality control and checking).
- Another 28% are interested in searching databases to understand what data are available and if a particular need can be met by a pre-existing dataset.
- 24% indicated that their aim is to directly download data products (interpolated, aggregated or derived data from analysis or models).

Interestingly, 13% of respondents indicated that they were seeking to link to data, via Application Programming Interfaces or APIs, Web Map Services, Web Feature Services or other. This is a relatively recent data user activity that may grow for marine data centres, as machine to machine tools are increasingly used to link up different databases (Pendleton et al., 2019[27]). It potentially constitutes an important evolution in marine data access and management, allowing databases to become more interconnected and user friendly for a range of users, many of whom may regularly pull datasets into their systems.

Figure 3.1. Many reasons for visiting a marine data archive/management centre

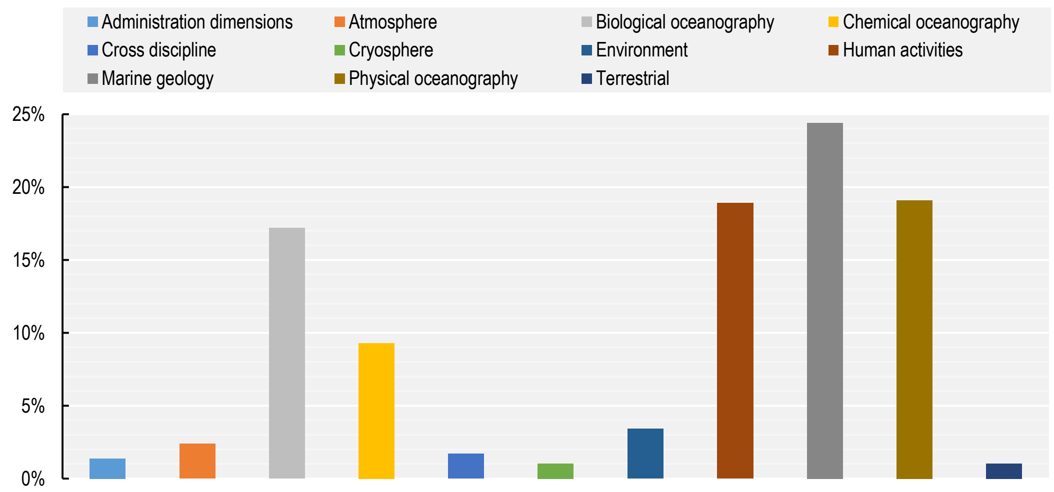


Note: Individual respondents could select multiple options and the number of options selected is not uniform for every respondent. The total number of responses for this question is 375.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

Users linking to marine data through Application Programming Interfaces, and other routes such as Web Map Services, Web Feature Services or other technologies, are interested in a range of marine data parameters (Figure 3.2). Marine geology comes first (24%), followed by physical oceanography (19%) and terrestrial data, including characterisation of the land surface (e.g. land surface temperature, vegetation) (also at 19%).

Figure 3.2 Users linking to data through APIs and other routes are interested in a range of marine data parameters

Proportion of total count of parameters according to broader data categories for respondents linking to data



Note: Respondents could select from a list of marine data parameters corresponding to the SeaDataNet P03 parameter vocabulary (see 5.4.Annex B for detailed categories). For respondents that selected the linked data option for accessing marine data, the number of P03 parameters selected has been aggregated under P08 categories and the count divided by the total number of P03 parameters in each P08 discipline.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

Respondents were also asked about the frequency of their use of the repository data they download, view, and/or link to. This is important information for data management and archiving centres, as they need to be able to meet the needs of both regular users and ad-hoc users. Some 31% of the respondents reported regular uses (daily, weekly, monthly), and less than 1% of respondents mentioned annual uses of data. However, some 43% mentioned that they use marine data every now and then, but with no pattern to their data use, and some 14% mentioned they used data from the data archive/management centre only once or a few times.

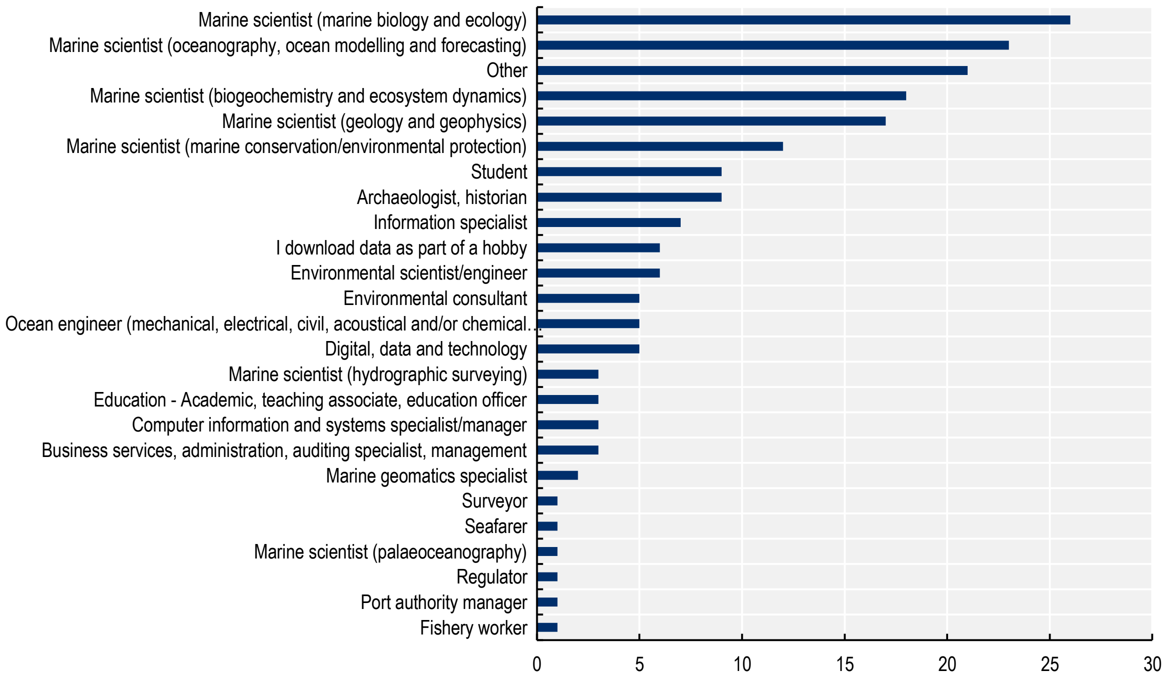
3.3. Who are the marine data users: Many scientists… but not only

The MEDIN Data Archive Centres have committed to making their data holdings openly available wherever possible, removing barriers to data access such as having to register for or pay for the services provided. For this reason, users of data from these repositories are typically anonymous. Nonetheless, this survey provides interesting insights into their user base.

In terms of the survey respondents' occupations, the majority of users are unsurprisingly scientists (Figure 3.3). A wide variety of marine data are collected by scientific research programmes for research purposes, which tends to make ocean science a primary user of marine data (IOC, 2017[28]). Scientists are making use of their own data, but they also depend on data collected by others. In the survey, more than 50% of respondents are marine scientists, involved in marine biology and ecology (14%), oceanography, ocean modelling or forecasting (12%), biogeochemistry and ecosystems dynamics (11%), geology and geophysics (9%), marine conservation (6%) or hydrographic surveying (2%). Students represent 5% of the respondents. Data and geomatics specialists, computer information and systems specialists represent another interesting category totalling 11% of respondents.

Figure 3.3. While many respondent's occupations revolve around marine science, a substantial number of respondents work in other ocean economy relevant domains

Number of respondents from each occupation



Note: No internationally agreed classification of occupations suitable for analysis of ocean, marine and maritime domains exists at present. The list of occupations was established through a consultation process with collaborating data archive centres. The freehand inputs to the "other" option included: marine license manager, data processor, nautical faculty, historical weather reconstruction, retired emeritus fellow, political scientist, economist, public service, marine construction engineering, coastal consultant, researcher, ecologist, climate monitoring and climate data set creation, marine conservation manager, climate scientist, impact evaluation and international relations, marine conservation and MPA management, tourism research/ consultant, offshore wind energy visitor centre, dredging, and technology developer for offshore wind.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

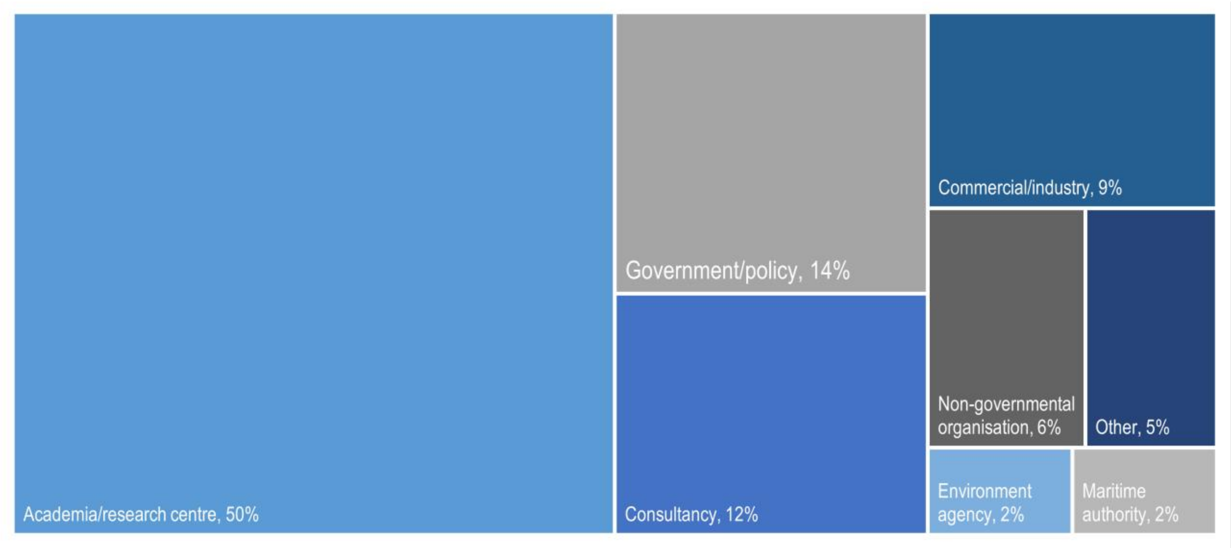
The majority of respondents are working in organisations located in the United Kingdom (82%) but replies were also received from users of 20 other countries. The United Kingdom, Australia, Germany, Ireland, Italy and the United States represent the top six countries for responses.

The survey respondents are also working in a wide range of sectors (Figure 3.4). Half of the respondents are engaged in academia and/or research centres. A little less than 20% are working in government/ policy areas (including 2% in environmental agencies, and 2% for maritime authorities). Another 21% are employed in the private sector, with some 12% working in consultancy and 9% in industry. Respondents working for NGOs (6%) and other organisations (5%) constitute the remainder.

Among the respondents from the private sector, there are specialised, intermediary, small to medium sized enterprises who supply value-added products and services to specific sectors and develop solutions for specific end-users in the maritime sector. Their activity draws on public marine data that are then commercialised in the form of more detailed, highly complex and often customised information products.

Figure 3.4. Marine data users work in a range of sectors

Percentage of total respondents from each sector



Note: Sectors are considered different to industry for the purposes of the survey. For example, a respondent could belong to academia but apply public marine data in the offshore wind and marine renewable energy industries.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

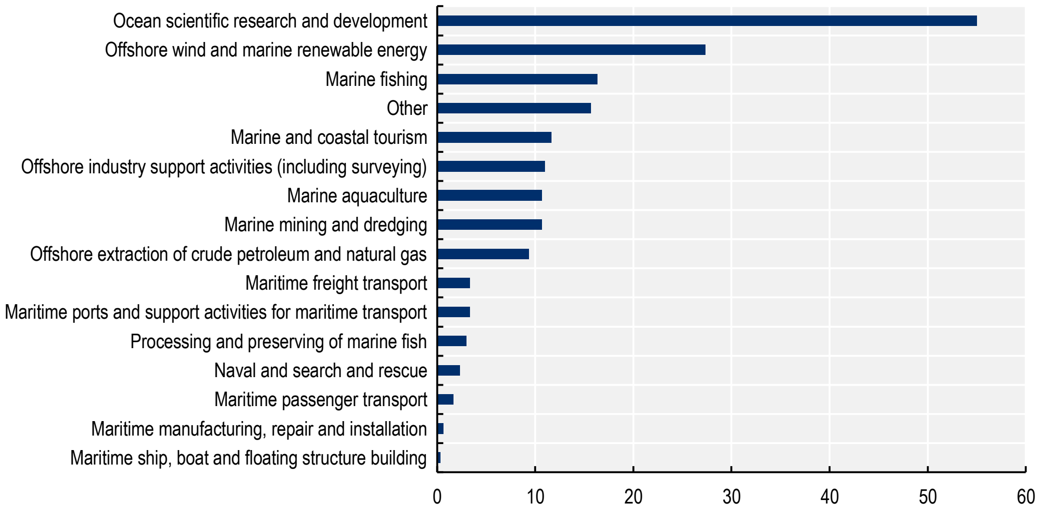
3.4. Public marine data are used in many industries, including for the development of revenue generating products

Public marine data are used and included in different products across a wide range of industries. Although there are still some challenges in effective engagement of marine data archiving and management centres with industry, the development of user-friendly interfaces tends to contribute to improve marine data uses in commercial products (Mcmeel et al., 2017[29]).

When examining the types of industries in which marine data are used the most, ocean scientific research and development comes first (with more than 50 counts) (i.e. based on the count of industries selected by respondents, weighted by the importance of each industry in the respondents' overall activities) (Figure 3.5). Offshore wind and marine renewable energy (28 counts) and marine fishing (17 counts) follow. Other industries of importance for the UK marine data users include marine and coastal tourism, offshore industry support activities (including surveying), marine aquaculture, marine mining and dredging, and offshore extraction of crude oil and gas.

Figure 3.5. Public marine data are used across a range of industries, including several such as offshore wind and marine renewable energy that are burgeoning ocean economic activities

Count of industries selected by respondents weighted by the importance of each industry in the respondents' overall activities

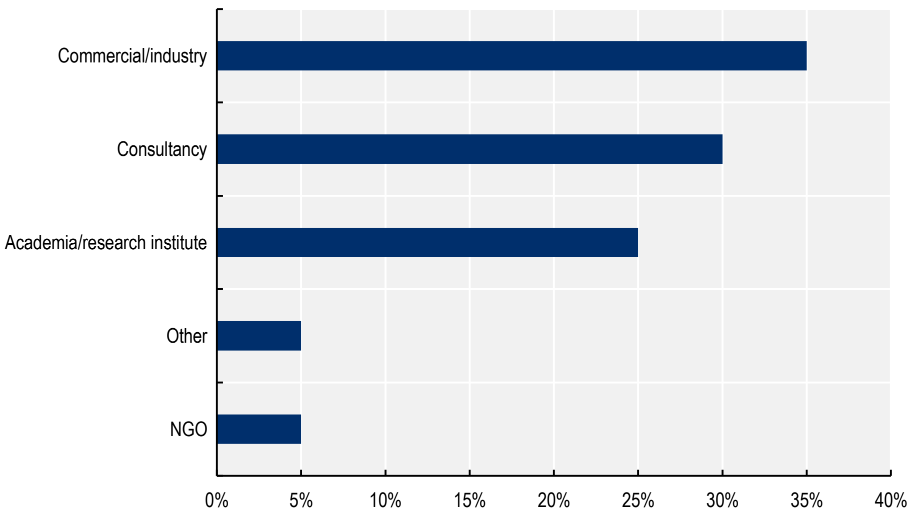


Note: The list of industries corresponds with the OECD's list of ocean economic activities. Respondents were able to select three industries from the list and were asked to rank the importance of each industry selected in their overall activities.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

Some respondents confirmed that they use public marine data in revenue generating products, suggesting the existence of value added activities (Figure 3.6). Some 35% of the respondents who use data to make products come from the commercial sector, and 30% from consultancies. Academia and research institutes are also using public marine data to create revenue-generating products (25% of this category), as are 5% of the NGOs.

Figure 3.6. Some of the marine data downloaded from data archive centres are used in revenue generating products, suggesting the existence of value added activities

Percentage of respondents using data in revenue generating products from each sector

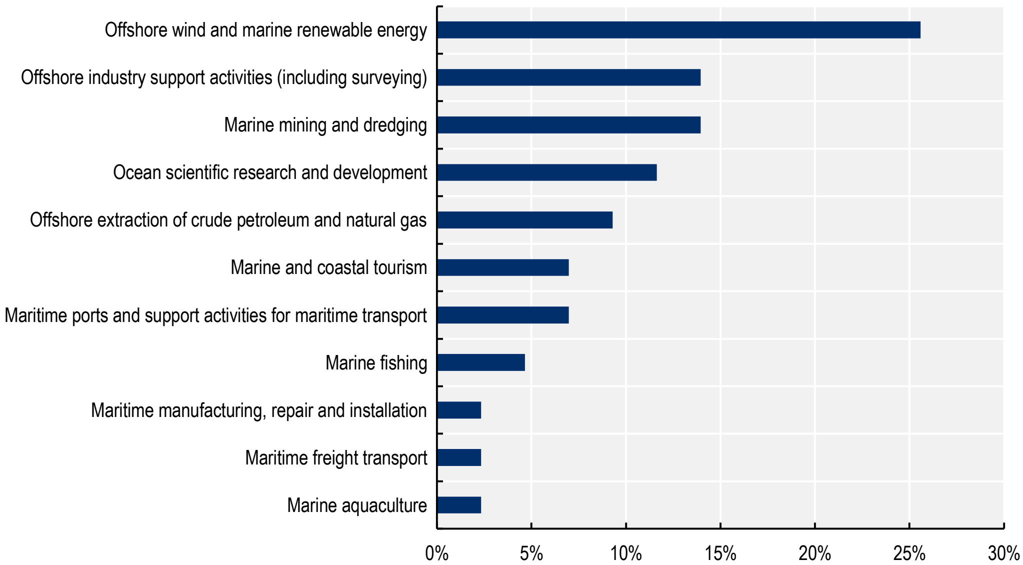


Note: Respondents were asked if the data are used in the production of a revenue generating product. 148 individuals responded "no", 20 responded "yes" and 17 did not answer. The chart corresponds with the 20 respondents that answered positively.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

The same respondents who are generating revenue with products using public marine data, are working with a number of specific industries (Figure 3.7). Some 26% are working with or for the offshore wind and marine renewable energy industry, 14% with offshore industry support activities (including surveying), and 14% with the marine mining and dredging industry. Other industries include ocean scientific research and development (12%), offshore extraction of crude petroleum and natural gas (9%), marine and coastal tourism (7%) and maritime ports (7%).

Figure 3.7. Respondents generating revenue with products based on public marine data are working in/with a number of industries

Industries in/with which commercial and industry sector respondents that generate revenue from data products work (expressed as a percentage of the total count of industries selected by the same group of respondents)



Note: The list of industries corresponds with the OECD's list of ocean economic activities. Respondents were able to select three industries from the list and were asked to rank the importance of each industry selected in their overall activities. For the purposes of this chart, the rankings are ignored.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

3.5. Following the flow of data demonstrates the spread of usage

Links between marine data and different sectors of the economy are on the increase, creating many more value chains as a result (OECD, 2019[1]). A value chain generally maps the relationship between data production, data processing, generation of data products, and the usage by different user groups. But marine data value chains are seldom linear, as the findings from the survey reveal.

Marine data users are accessing very different types of data, with some top categories emerging. These specific marine data are then used by organisations from different sectors (e.g. research centres, government agencies, commercial actors) in different fields of use, leading subsequently to a range of different actions. The next sections describe these data flows.

Types of data and sectors of uses

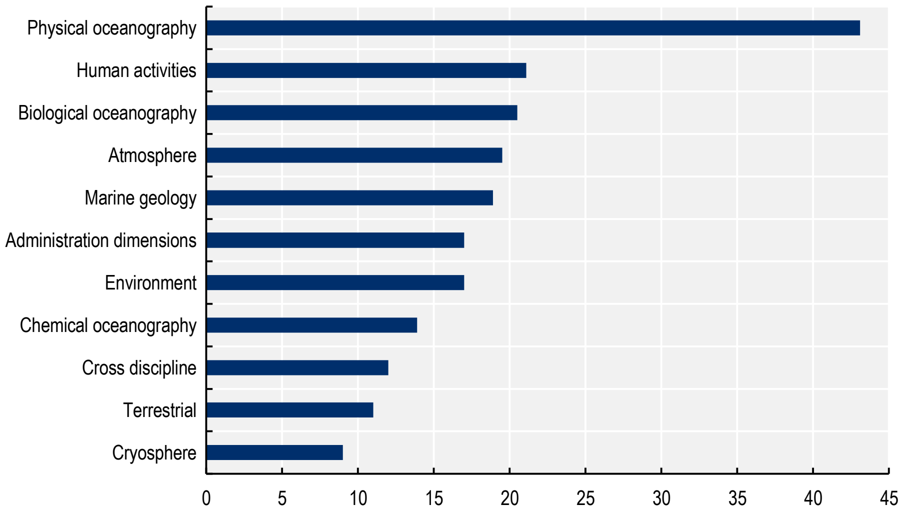
Respondents were asked to describe the types of marine data they were accessing (Figure 3.8). The top three types of marine data comprise physical oceanography (43%), human activities (21%) and biological oceanography (20.5%).

The different marine data groupings are based on the widely used SeaDataNet categories (see also 5.4.Annex B for a description of selected parameters and categories). Physical oceanography data are downloaded the most, since the physical properties of the ocean and their interaction influence and control many other aspects of the marine environment. Human activities data also represent an important category for marine data downloads, as they document the activities of man that have an effect on the Earth System. They range from aquaculture, pipelines and cables to hydrocarbon extraction and transport data. A third category, biological oceanography is also an important field of marine data use, not only for research but also as part of environmental impact assessments, many of which are taking place in the UK.

Other categories of marine data accessed (representing 17-19% each) include atmospheric data, marine geology, administration dimensions (typically temporal and spatial coordinates, with cadastral information) and environment data. The environment data domain in particular includes "the habitat (physical, biological or chemical conditions) surrounding an organism or a group of organisms, or factors affecting any part of the earth ecosystem past and present".

Figure 3.8. Data used from archive and management centres range widely across the types of marine data

Normalised count of data types used according to SeaDataNet P08 parameter disciplines



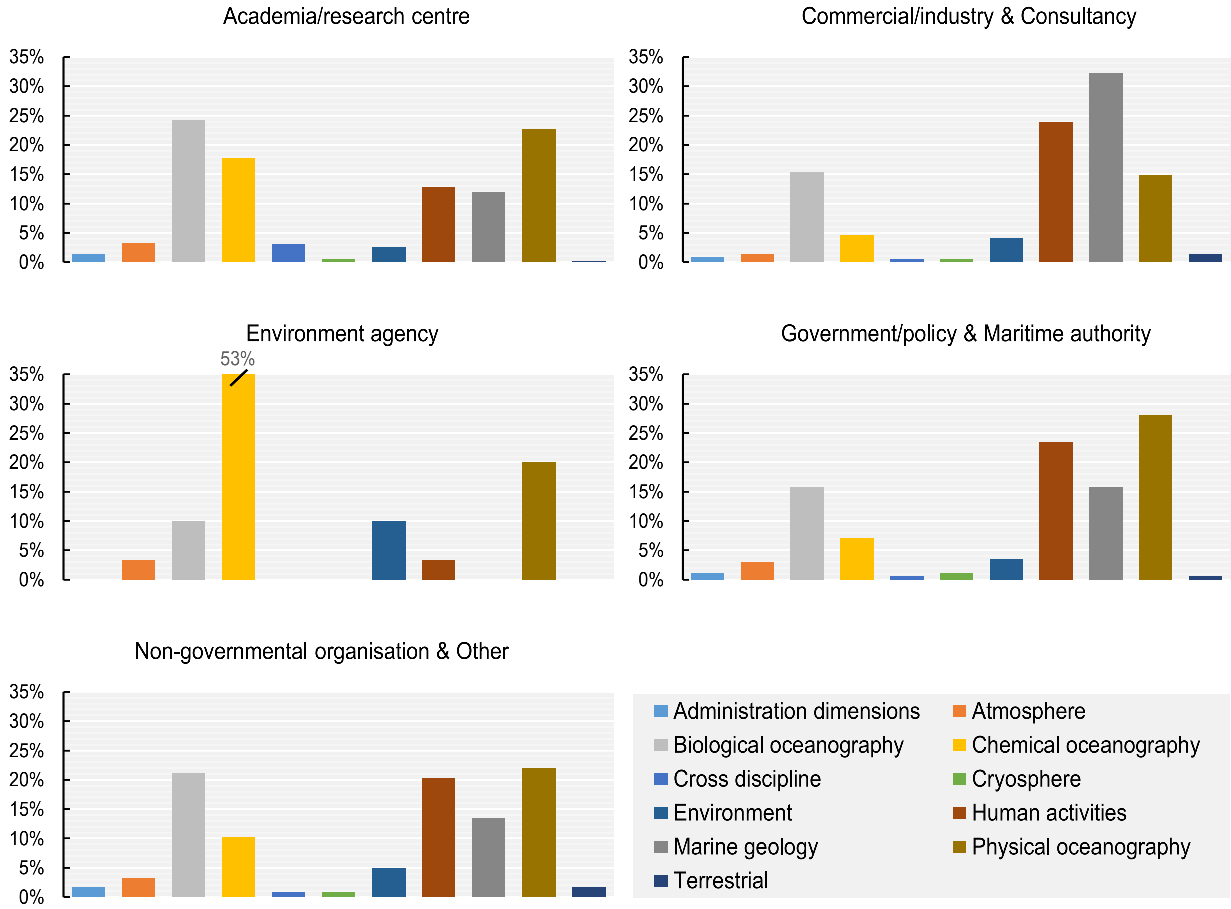
Notes: Respondents could select from a detailed list of marine data parameters corresponding to the SeaDataNet P03 parameter vocabulary. The number of P03 parameters selected has been aggregated under P08 categories and the count divided by the total number of P03 parameters in each P08 discipline. The P08 categories and P03 parameters are defined in 5.4.Annex B.
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

Specific marine data categories are then used in diverse sectors (Figure 3.9). Six types of sectors of marine data uses have been identified: academia/research centres, commercial actors including industry and consultancy users, government agencies, maritime authorities, environment agencies, non-governmental actors and others. The objective was to map the type of data respondents from these different sectors were using as a priority.

- Physical oceanography data are used extensively across all the different sectors.
- Academia and research centres are focused around the three core discipline areas for oceanographic research: physical, biological and chemical oceanographic data.
- Commercial actors, including industry and consultancy users, make extensive use of marine geology data (33%), human activities data (ranging from aquaculture, pipelines and cables to hydrocarbon extraction and transport data), physical oceanography, biological oceanography and chemical oceanography datasets.
- Governmental agencies involved in marine policy and regulations, including maritime authorities, mirror the commercial actors in their data uses, although they make greater use of physical oceanography and human activities data.
- Environmental agencies represent here a separate sector as they have slightly different needs. Chemical oceanography is the top data category for these agencies (53%), with human activities coming in second place, possibly linked to their role in marine pollution control.

Figure 3.9. Different data types are important in different sectors

Proportion of the total number of parameters selected, by discipline, by sector of respondent



Note: Respondents could select from a detailed list of marine data parameters corresponding to the SeaDataNet P03 parameter vocabulary. The number of P03 parameters selected has been aggregated under P08 categories and the count divided by the total number of P03 parameters in each P08 discipline. The P08 categories and P03 parameters are defined in 5.4.Annex B.
Source: OECD, MEDIN & GOOS (2020) *Users of public marine data survey*

Following the flow of data from fields of use to actions

The organisations representing different sectors of marine data uses have understandably very different fields of use, from marine science, to offshore oil and gas, or marine archaeology. For each of these different sectors, it is instructive to link the fields of marine data use (i.e. climate science, coastal protection) to the types of actions that can be taken based on the data. This is an essential mapping exercise, as it enables inferences to be drawn at a later stage about the value created. Five sectoral examples are provided in the Figure: academia/research centres; commercial actors, including industry and consultancy; government agencies, including maritime authorities; environmental agencies; and non-governmental actors.

Respondents from academia/research centres appear to use marine data primarily in marine science, climate science and policy development/marine management. Other fields include conservation, coastal protection and education. These fields of activity lead to a number of actions, the most common of which are unsurprisingly research and development, followed by raising awareness and supporting education. Interestingly, the range of other actions based on marine data is quite wide, e.g. validating data from elsewhere, managing marine resources, and analysing risks and policies.

Figure 3.10. Users from different sectors use data in different fields for different purposes

Fields of use for marine data, and the actions taken with them, by groups of respondents according to the sectors with which they associate

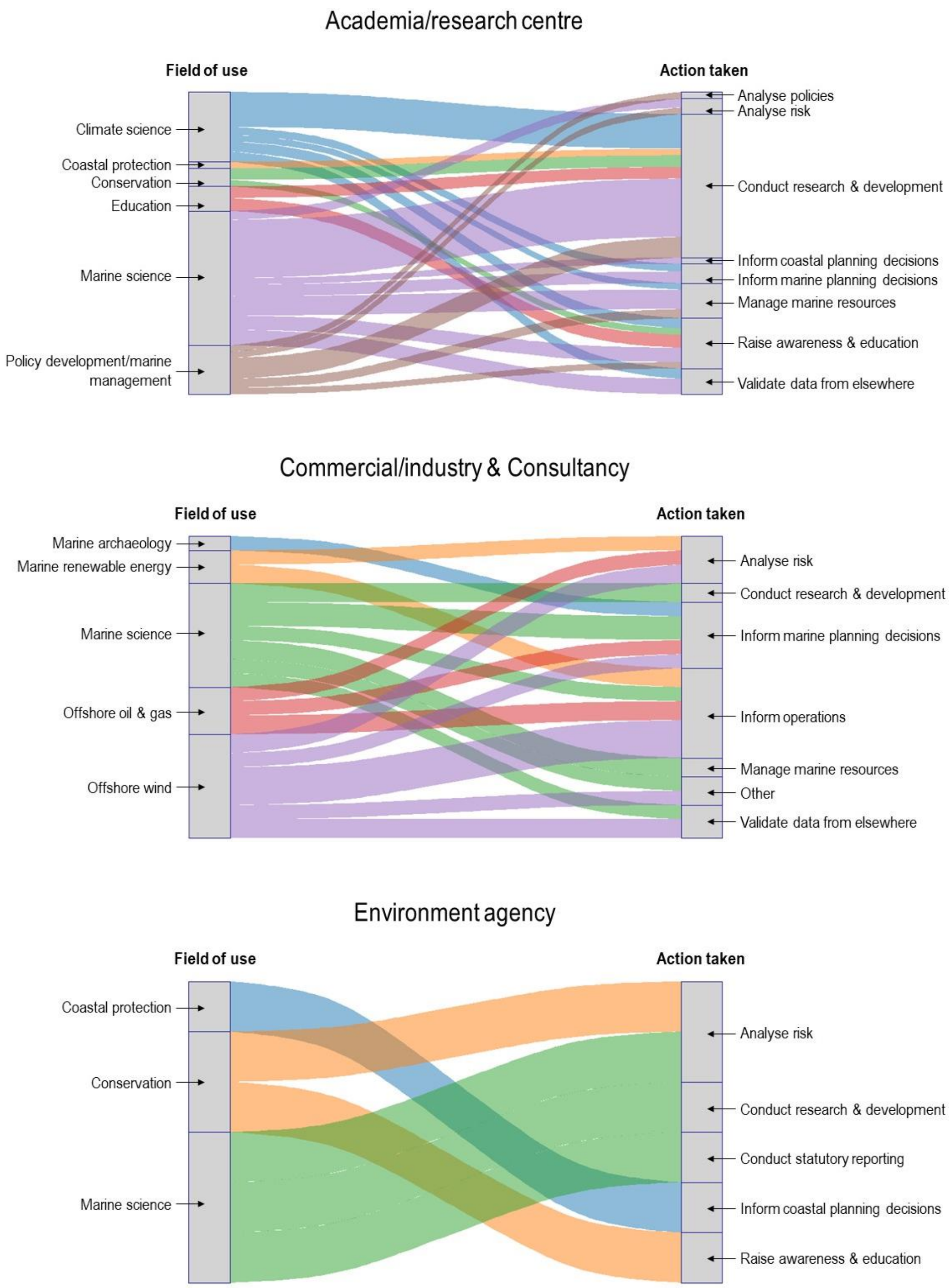


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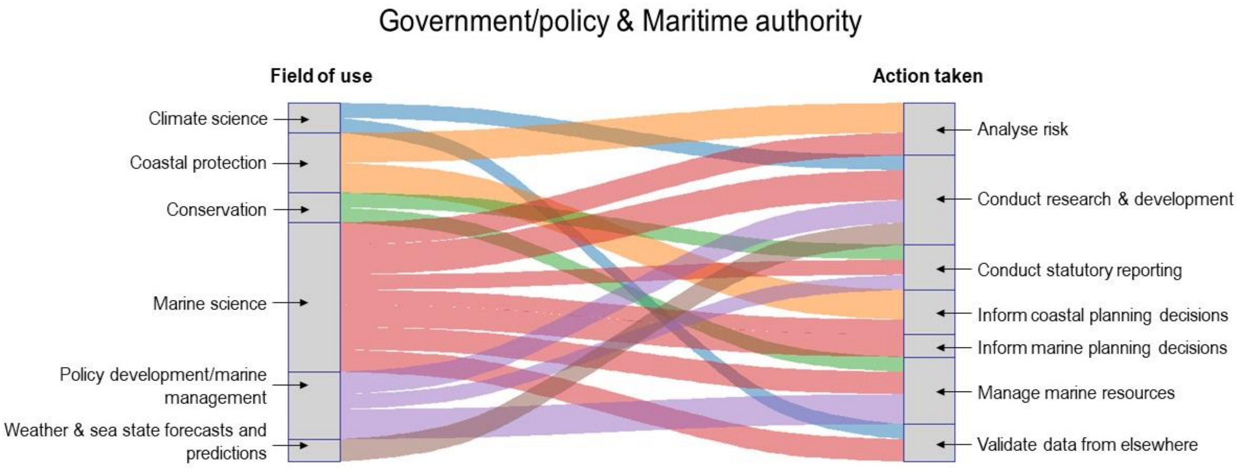
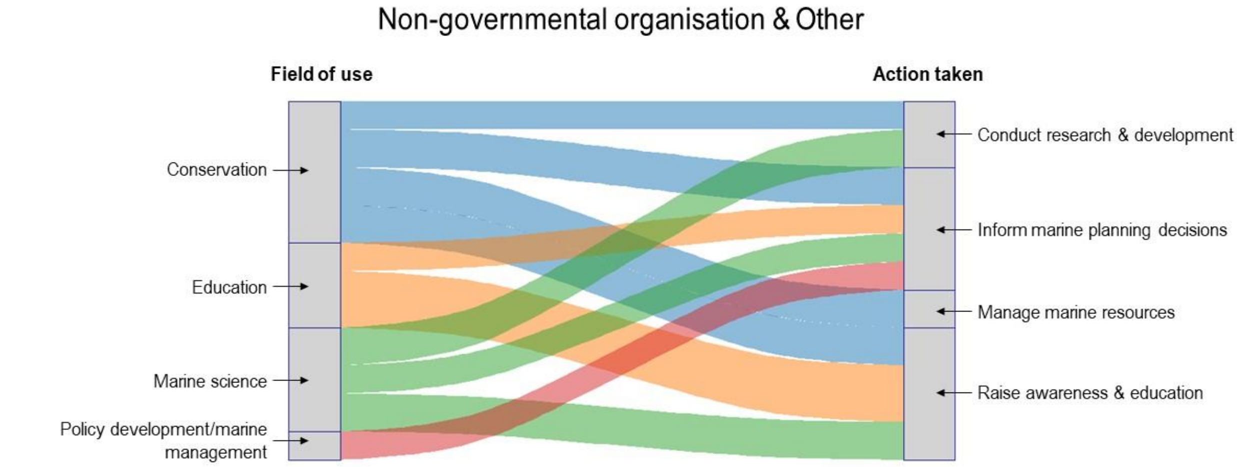
Figure Cont. Users from different sectors use data in different fields for different purposes





Note: The count of co-occurrences of fields of use and actions taken in respondents from comparable sector groupings, as indicated by the thickness of the lines linking field of use with action taken. The academia/research centres chart displays all co-occurrences with a frequency of more than 4. The commercial/industry and consultancy chart displays all co-occurrences with a frequency of more than 2. The environment agency chart displays all co-occurrences with a frequency of more than 0. The government/policy and maritime authority chart displays all co-occurrences with a frequency of more than 1. The non-governmental organisation and other chart displays all co-occurrences with a frequency of more than 2.
Source: OECD, MEDIN & GOOS (2020) *Users of public marine data survey*

The specifics of use and action in each sector are an important part of the survey, providing insight into an end-to-end value – from observation to action. The differences between sectors also provide some initial insight into actions where marine data is used.

In the academia and research sector, the key use areas are climate and marine science, with policy development / marine management representing also important fields. The data are primarily for research and development actions, however informing planning decisions and managing marine resources are also areas of significant activity. To validate data collected from elsewhere also comes up an activity, in several of the sectors. Interestingly raising awareness and education is also a significant activity.

Respondents from the commercial sector, including industry and consultancies, have five main fields of activity where they use marine data the most: marine science (i.e. providing specialised services and products to support scientists and public organisations), offshore wind, marine renewable energy, offshore oil and gas, and marine archaeology. These fields of activity lead then to concrete actions as shown in the flow chart. Risk analysis, informing marine planning, managing marine resources and informing operations (the prevalent category) form a large proportion of the activity associated with marine data in this sector (Figure 3.10).

Specifically, with respect to offshore wind (purple flows), the top actions for the commercial data users are to inform operations, analyse risk, validate data from elsewhere, and inform marine planning decisions. Although, the siting of offshore wind platforms has always been reliant on geospatial marine data, what is new is the growth in these commercial activities and the use of much broader marine data types in the decision-making process (e.g. from geology to biological oceanography data). The availability and usefulness of marine data from public repositories is clearly supporting the development of this industry. And the use of marine data could grow further because of the need to monitor activities, operate platforms safely, limit environmental damage (e.g. impacts of offshore wind on marine ecosystems and their fauna), but also because of regulations that require new actors to make use of the data and demonstrate the sustainability of their activities. This is a good illustration of initial public marine data held in data archiving centres being transformed into valuable information for decision-making in the private sector.

With regard to government actors, including maritime authorities, there are a wide range of use areas including marine and climate science, coastal protection, conservation, policy development and a new category of weather and sea state forecasts. Equally, the data are used in a variety of actions, risk analysis, statutory reporting, informing planning decisions for marine and coast, research and development and managing marine resources. Data are also used to validate data from elsewhere.

For the environmental agencies in particular, the data is sparse and so the information on this use sector can be taken only as an initial indicator. However, the use area and action analysis shows that marine science is also important for this sector, with coastal protection and conservation representing also large fields of use. Again, risk analysis is more important for this sector than academic/research sector, and is from this dataset the most important action taken with the data. The data is also used for research and development, to inform coastal planning decisions and to raise awareness and education, and statutory reporting.

Finally, concerning NGOs and other sectors, conservation features as a more significant use area, education, and marine science are also important. Informing marine planning decisions, research and development, managing marine resources and raising awareness and education are important areas of activity.

These different sectors and patterns of action for which marine data is used begin to build up a picture around public data use, and valuable to inform dialogues with the sector around their data needs and requirements. This is an initial view, and more surveys are needed to deepen the understanding of public marine data use.

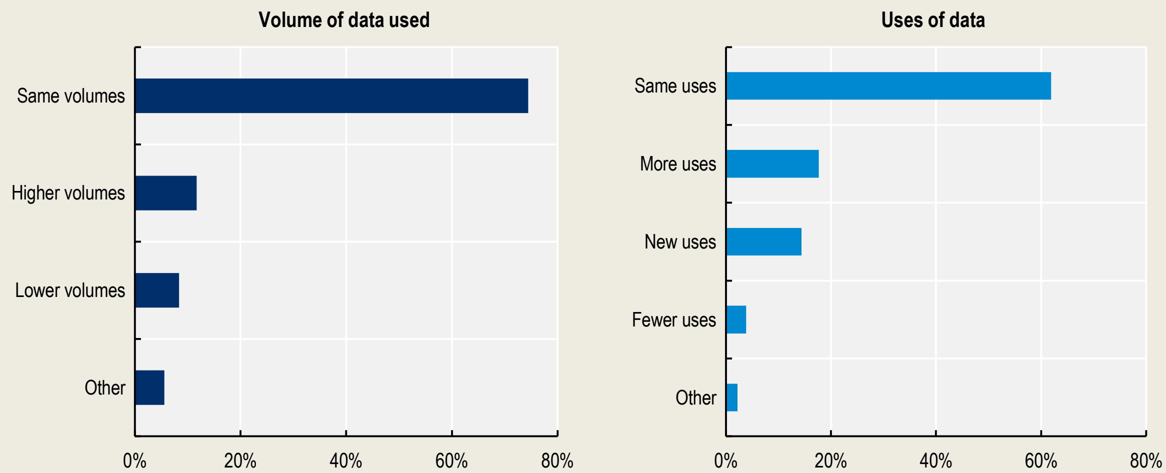
As part of the survey, the different marine data users were also asked whether the COVID-19 crisis would impact their expected uses. As shown in Box 3.1, most of the users did not expect the COVID-19 pandemic to substantially change their uses of the data. Still, this may be different today as some datasets due to be updated or uploaded to data centres in 2020 and early 2021 were never collected, as many research vessels were grounded for months (Heslop, Fischer and Tanhua, 2020[30]).

Box 3.1. Users of public marine data do not expect the COVID-19 pandemic to substantially change their uses of the data

When asked about the impacts of the COVID-19 crisis on their expected uses of marine data, respondents were quite confident that they would keep the same uses and volumes of data downloads (Figure 3.11). Although the survey was conducted in the first phases of the pandemic (first semester 2020), most of the impacts of the crisis were occurring at the level of the marine data collection not at the data distribution levels (Heslop, Fischer and Tanhua, 2020[30]). This may change as some datasets due to be updated or uploaded to data centres in 2020 and early 2021 were never collected.

Figure 3.11. Users of public marine data and the COVID-19 pandemic

Percentage of total respondents agreeing with each statement concerning likely impact of Covid-19 on the volumes of data use and the ways the data are used



Note: Options available to respondents concerning the volume of data uses were: "I will download the same volumes of data", "I will download higher volumes of data", "I download lower volumes of data", and other options concerning uses were: "My uses will remain the same", "It will encourage more uses", "It will encourage new uses", "It will encourage fewer uses", and "Other".
Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

3.6. Describing the benefits of marine data based on the survey results

Developing and sustaining marine data collection and distribution require significant public support. As with all public investments, a thorough assessment of the associated costs and benefits is useful to understanding their value to society. The costs of marine observations and of the required data management and archiving architecture can be relatively easy to identify (i.e. initial cost of capital, deployment and maintenance costs). In comparison, the benefits derived from marine data are broad, often poorly identified, with few currently quantified in a meaningful way and with many of the wider benefits difficult to value monetarily.

When assessing the value of marine data, a key characteristic is that they are non-rival. Data can be used for multiple purposes at the same time without degenerating or being "used-up". As an example, scientists often collect marine data, and share them in repositories for reanalysis by other scientists or other users. Socio-economic benefits derived from marine data are therefore multiple and varied (Rayner, Jolly and

Gouldman, 2019[6]). By definition, marine baseline data – i.e. physical and chemical parameters, combined with biological data – provide evidence that supports the management of marine operations and conservation efforts. This critical input for decision-making can be measured in different ways.

In the UK survey, respondents were asked to provide comments on the types of benefits they draw from marine data. An initial text analysis detected several combinations of words which point to some of the possible benefits respondents derived from using the data management/archive downloads, e.g.: "data collect", data process", as well as "available data", "useful data", "crucial datasets, "and access "difficult (to find) data" (Figure 3.12).

Figure 3.12. Most frequent combinations of words in individual sentences in responses to benefits question

nouns and adjectives *nouns and verbs*

Source: OECD, MEDIN & GOOS (2020), *Survey of public marine data users.*

Digging deeper into the benefits revealed by respondents to the questionnaire, two main categories surfaced: those that suggest that marine data contribute to greater/better knowledge or improved tools, and those that suggest distinct economic benefits.

Marine data contribute to greater/better knowledge or improved tools

According to the qualitative statements made by respondents, marine data are deemed:

- Key/essential/invaluable to informing and supporting decision making and planning (including marine spatial planning) and to supporting policy making;
- Essential inputs to modelling;
- Important for providing established, legitimate, well-founded, reliable, robust and authoritative data frameworks for validating results;
- Very useful/invaluable for educational purposes;
- Helpful in filling knowledge gaps.

Marine data also generate economic benefits

In many cases, marine data also generate direct and indirect economic benefits, including "value-added" benefits, as they contribute to validate other data sources, thereby enhancing their value.

Economic benefits mentioned by respondents include:

- Contributing to more efficient operations;
- Providing baseline conditions so as to eliminate or greatly reduce the need for costly on-site surveys at the outset of operations, avoiding duplication of effort etc.;
- Helping avoid costs encountered further downstream by identifying early on specific risks, potential constraints and particular engineering challenges.

4. Next steps in valuation

The results of this survey of selected marine data users in the UK provide useful information in terms of mapping the users of marine data, data flows and value chains. As the next steps in valuation, suitable methodologies need to be assessed and the specificities of marine data reuse need to be taken into account. In addition, new surveys in different parts of the world will contribute to build the knowledge base by enabling further value chains to be mapped. These next steps in the process of valuing public marine data are described below.

4.1. Assessing suitable valuation methodologies for marine data value chains

Estimating the socio-economic benefits of marine data requires an understanding of the value chains associated with user groups and their use of products and services. When both the value chains and user groups are clearly mapped, the marketable value associated with marine data can become more straightforward to calculate. That next step requires the development and application of suitable valuation methodologies, and the need to take into account the importance of the reuse of public marine data.

Valuing components of marine data value chains

Although marine data users are increasing in number and diversity, relatively few studies so far have aimed to understand how information on value is interpreted and used by decision makers.

There are however a number of methods that can be used to demonstrate how marine data can improve efficiency, productivity and the cost structure of many ocean-related activities, thereby generating benefits that may be valued monetarily if the appropriate methodology is pursued (Table 4.1).

Table 4.1. Socio-economic benefits associated with sustained marine observations

Direct economic benefits	Revenues associated with the sale of information products derived, in whole or in part, from ocean observations.*	E.g. Sale of sea surface temperature products used by the commercial and sport fishing industries to aid in the location of target fish species.
Indirect economic benefits	Gains in efficiency or productivity derived from an information product or service resulting in whole or in part from ocean observations (i.e. costs savings, cost avoidance and increased revenues).	E.g. Better ship routes as a result of accurate sea state forecasts, valued, for example, by reduced fuel costs as a result of avoiding rough seas.
Societal benefits	Benefits received by society in ways that are often easier to identify than to quantify, including particularly improved ocean governance.	E.g. improved environmental management valued, for example, by estimation of the avoided costs associated with mitigation, or by the monetary sanctions in case of pollution ('polluters-pay' principle).

Note: *Many of these commercial products are based in part on free data made available by publicly funded open data platforms.
Source: Adapted from OECD (2019[1]).

Concerning specifically the valuation of data from sustained ocean observations, OECD (2019[1]) outlines methodologies used in a number of relevant articles and policy papers.

- The most prominent method in the literature reviewed (45% of sources) relies upon a guesstimate of the impact of ocean observations on particular economic sectors according to some arbitrary percentage – usually Nordhaus's proposed one per cent (Nordhaus, 1986[31]) – of a target value. For example, Kite-Powel (2008[11]) use Nordhaus's one per cent to find the benefit of ten coastal ocean observing systems to industrial output in the United States to be in the order of multiple millions of US dollars.

- The second largest category of applied methodologies (35% of the reviewed literature) relates to a field of economics known as “decision theory under uncertainty”. Decision theory provides a set of methods for understanding the value of information (VOI) flowing from data used by decision makers. It is particularly suited to measuring the impact of data in operational settings. A brief summary of how decision theory under uncertainty provides estimates of the VOI is also provided in the report (OECD, 2019[1]).

Despite its apparent suitability, a takeaway from previous OECD work is that the ocean observing community is relatively unfamiliar with economic concepts related to VOI and unaware of the use of decision theory to value ocean data. This is likely to be because, anecdotally at least, there are still few economists working on ocean observations and the literature on the value of ocean observations data is small – only 35 studies met the minimum criteria for review.

Building on this knowledge base, more work is currently ongoing on methodologies appropriate for application in the valuation of information generated from public marine data, and forms one of the next steps in this exercise.

Valuing public marine data reuse

In the broader context of publicly funded data infrastructure, public data and their reuse generate substantial social and economic benefits. It is estimated that access to and sharing of data generate benefits worth between 0.1% and 1.5% of gross domestic product (GDP) in the case of public-sector data, and between 1% and 2.5% of GDP (in a few studies up to 4% of GDP) when private-sector data are included. The estimated magnitude of the effects depends on the scope of the data and the degree of data openness (OECD, 2019[3]).

Public marine data possess considerable scope for generating potential benefits (Tanhua et al., 2019[19]). The reuse of marine data in particular refers to the use of data acquired, assembled, analysed and stored for a purpose other than was initially intended, typically by a third party. The reasons for data reuse cannot be known in advance by the initial acquirer, suggesting the value of the collected data is in some cases only a small part of the potential of the original data (see Box 4.1). A major challenge for marine data management and archiving centres is therefore to communicate well to users the existence and long-term availability of complex sets of data, with the possibility to reuse such data for many different purposes.

The survey shows that marine data are being used across many different ‘downstream’ activities, in different sectors and to answer different questions, providing evidence of this use and benefit in both supporting operational efficiency and revenue generation. For the GOOS, this strengthens the need to support the flow of quality metadata with the data, as a key enabler of re-use. For MEDIN and its DACs, the pattern of use, combined with its knowledge of the impact of sector outreach activities, could lead to further targeted awareness raising with industry, government over the types of data available and useful to each sector.

One of the unforeseen issues linked to the growing push to make data openly available and remove hurdles to data reuse, is that data archive/management centres often have no record of who downloads and reuses data from their databases. Several data archive/management centres have published case studies of the use of the data disseminated by them, but a holistic picture of the use and reuse of marine data and their contribution to value creation more broadly does not yet exist. Further work in this area will be required.

Box 4.1. Encouraging the reuse of marine data: the example of bathymetric surveys

When drafting and updating maritime charts, a large amount of data is collected by way of hydrographic surveys, including bathymetric surveys with sparse soundings. The rich array of raw data collected can potentially be reused for a multitude of purposes:

- Full 3D seafloor modelling for engineering purposes (e.g. underwater construction; pipeline/cable laying; dumping and dredging operations);
- Seafloor type definition from backscatter data for sedimentary studies and engineering planning;
- Sound velocity data for oceanographic studies;
- Wreck and obstruction data in more detail than portrayed on charts (e.g. for historical studies, defence applications, recreational diving interest);
- And geodetic and tidal information for datum studies.

However, despite open data policies, often only a small amount of the accumulated knowledge (present in databases in raw data formats) is passed on to the recipients of the final map products, who may not even be aware of all the existing raw data. Consequently, in many cases only a fraction of the potential of the original hydrographic data sets, and particularly bathymetric survey data, is actually exploited. The challenge for marine data management and archiving centres therefore is to communicate well to users the existence and long-term availability of complex sets of data that can be reused for many different purposes.

Source: Adapted from International Hydrographic Organization (2017[32]).

4.2. New surveys to build up the knowledge base

This survey provides limited but detailed, first-hand information on marine data flows in the UK, associated with various recent UK policies. It would be pertinent to explore new marine data value chains with other data management and archiving organisations in different countries. New repeat surveys could be launched to build up the knowledge base and provide a variety of national examples.

A next step in future surveys could be to expand on text analysis techniques to extract more information on the benefits perceived by respondents. Topic modelling, for example, is a machine learning method that looks to probabilistically determine different topics apparent in large volumes of text. In this case, it could be applied to automatically categorising the responses to the benefits question. A limitation of these methods is that they are most appropriate for analysing a large number of documents containing a large number of words. As the samples of surveyed users grow, so may the use of these techniques be more suitable to uncover information on the uses and value of marine data that would otherwise be difficult to obtain.

5. Key findings and recommendations

This original survey of UK marine data has achieved its initial objectives. It is adding to the current understanding of marine data user communities, who are accessing publicly available marine data through repositories. Although based on a relatively small sample, it has produced first indications of the different pathways through which marine data are used and transformed into actionable information. And most importantly, it lays the foundations for future work in measuring the value of publicly available data by creating selected systemised value chains of their use. Key conclusions and recommendations are detailed below.

5.1. Recap on the rationale and basis for the analysis

An assessment of the costs and benefits of collecting, distributing and archiving public marine data is necessary in order to understand their value to society. As with all public investments, such assessments provide evidence to decision makers and, if deemed beneficial overall, help to sustain public funding.

The analysis presented in this paper was based on a co-designed survey of the marine data users associated with MEDIN and its partnering Data Archive Centres (DACs). The survey was structured in such a way as to elicit original information that could be used to map value chains - beginning from the data management and archiving systems providing access to the data, to the users' characteristics (occupation, sector), their data needs, their selection of data, all the way to their initial data uses. Although only a self-selected sample of data repository users from MEDIN DACs was surveyed, and not the full population of UK marine data repository users, the results nonetheless provide informative insights into the variety of marine data users in the UK. The survey results also shed light on the spread of marine data usage within the sample of respondents, and illustrate with the help of systematised value chains how different data types are used by different groups of users, flow between sectors of the economy, and across various fields of use and actual actions taken.

5.2. Key findings on the evolving uses of marine data in the UK

A diverse and complex landscape: The marine data landscape in the United Kingdom is diverse and complex, as users access marine data via many different routes. As an illustration, 31% of the survey respondents accessed the survey through the MEDIN portal, however many others accessed it directly via partnering Data Archive Centres and up to 20 additional access routes were mentioned. The multiple sources of marine data in the UK demonstrate the complexity of the landscape.

The rise of machine-to-machine connections in marine data management: The survey identified a recent evolution in marine data access and management. As databases become more interconnected and user friendly for a range of users, the importance of Application Programming Interfaces or APIs emerged. A notable share of survey respondents (13%) indicated that they were linking to marine data through Application Programming Interfaces, Web Map Services, Web Feature Services or other tools. This is an important data user activity that may grow for marine data centres, as machine-to-machine tools are increasingly used to link up different databases. The survey results suggest that multiple data types are linked via APIs and other web services: marine geology (24%), followed by physical oceanography (19%) and terrestrial data (e.g. land surface temperature, vegetation etc.) (also at 19%).

From raw marine data to value adding data products, there are a broad range of reasons for users to visit data archive centres: Of the different reasons for visiting DACs given to respondents to select from, the downloading of raw datasets (unprocessed or calibrated data that may have undergone basic quality controls and checking) (29%); database searches to understand what data are available and whether a particular need can be met by a pre-existing dataset (28%); and the direct download of data products (interpolated, aggregated or derived data from analysis or models) (24%), were similar in terms of the number of times they were selected (respondents could select more than one answer).

Differences exist among respondents in the frequency of data use: Information about the frequency with which marine data users download, view, and/or connect with repositories is important for data management and archiving centres, as they need to be able to meet the needs of both regular and ad-hoc users. Some 31% of the responses reported regular uses (daily, weekly, monthly), and less than 1% of responses indicated annual use of data. However, some 43% of responses indicated use every now and then without a noticeable pattern, and some 14% of responses indicated only a few times per year.

5.3. Key findings on the value chains of UK marine data uses

A diverse marine data user-base: The MEDIN DACs have committed to making their data holdings openly available wherever possible, by removing barriers to data access such as the requirement to register for the services they provide. For this reason, users of data from these repositories are typically anonymous. Although based on a limited sample, this survey nonetheless offers insights into the wide range of users accessing these databases.

- More than half of respondents are marine scientists, involved in marine biology and ecology (14%), oceanography, ocean modelling or forecasting (12%), biogeochemistry and ecosystems dynamics (11%), geology and geophysics (9%), marine conservation (6%) or hydrographic surveying (2%). Students represent 5% of the respondents. Data and geomatics specialists, computer information, and systems specialists represent a further category totalling 11% of respondents.
- Half of the respondents are working in academia and/or research centres, 21% are working in the private sector, 12% being engaged in consultancy and 9% in industry, and a little less than 20% are employed in government/ policy areas (including 2% in environmental agencies, and 2% for maritime authorities). Respondents working for non-governmental organisations (6%) and other organisations (5%) constitute the remainder. Among the respondents from the private sector, there are specialised, intermediary, and small to medium sized enterprises developing tailored solutions for specific end-users in the maritime sector or for their own use. In a few cases, their activity draws on public marine data that are then commercialised in the form of more detailed, highly complex and often customised information products.

Public marine data are used to develop commercial products: Private sector users, as well as some research centres, are developing revenue-generating products based on public marine data. Some 26% of respondents developing commercial products are working with or for the offshore wind and marine renewable energy industry, 14% with the offshore industry support activities (including surveying), and 14% with the marine mining and dredging industry. Other industries include ocean scientific research and development (12%), offshore extraction of crude petroleum and natural gas (9%), marine and coastal tourism (7%) and maritime ports (7%).

Multiple industries of the UK's ocean economy use marine data made available through DACS: Of the ocean based industries from which respondents could select from, respondents use marine data the most in ocean scientific research and development, followed by offshore wind and marine renewable energy, and marine fishing. Other industries of importance for UK marine data users that responded to the survey include marine and coastal tourism, offshore industry support activities (including surveying), marine aquaculture, marine mining and dredging, and offshore extraction of crude oil and gas.

Mapping systemised UK marine data value chains: Links between different types of marine data and different sectors of the economy are multiple and varied, spawning many complex value chains as a result. Generally, value chains are a useful concept for mapping the relationship between data production, data processing, generation of data products, and usage by different user groups. But marine data value chains are seldom linear, as the findings from the survey reveal.

- *Types of marine data accessed:* Marine data users are accessing very different types of data, with some top categories emerging, namely physical oceanography (43%), human activities (21%) and biological oceanography (20.5%). Physical oceanography data are understandably the most downloaded, since the physical properties of the ocean and their interaction influence and control many other aspects of the marine environment. Data on human activities also represent an important category of marine data downloads, as they document activities that tend to have an important impact on the environment, e.g. aquaculture, pipelines, cables, hydrocarbon extraction, transport. The third category, biological oceanography, is also a major field of marine data use, not only for research but also as part of environmental impact assessments and definition of Marine Protected Areas.
- *Sectors using marine data:* these comprise academia/research centres, commercial entities including industry and consultancies, government agencies, maritime authorities, environment agencies, and non-governmental actors.
  - Physical oceanography data are used extensively across all the different sectors.
  - Commercial actors make extensive use of data on marine geology, human activities (ranging from aquaculture, pipelines, and cables, to hydrocarbon extraction and transport), physical oceanography, biological oceanography and chemical oceanography.
  - Governmental agencies involved in policy making mirror the commercial actors in their data uses, although they make more direct use of physical oceanography and human activities data. Chemical oceanography is the top data category for the environmental agencies (53%), with human activities coming in second place, possibly linked to these agencies' role in marine pollution monitoring and control.
- *Types of action supported by marine data analysis:* The findings of the survey indicate that different groups use marine data for very diverse purposes. With respect to the commercial/industry sector, the main fields of marine data use are marine science (providing specialised services and products to support scientists and public organisations), offshore wind, marine renewable energy, offshore oil and gas, and marine archaeology. Within this group, marine data serve to inform operations (the largest category), but also contribute to spatial planning decisions and support risk analysis. Specifically, within the offshore wind sector, for example, the top actions for commercial data users are to inform operations, analyse risk, validate data from other sources, and inform marine planning decisions. Although the siting of platforms at sea has always been reliant on geospatial marine data, there is now a stronger requirement for access to a much broader range of marine data (e.g. biology, environment). This underlines further the essential role of marine data from public repositories, with respect to government agencies, NGOs, and research centres.
- *Benefits derived from marine data.* The benefits derived from public marine data are manifold . Marine data contribute to greater/better knowledge or improved tools, and economic benefits. These include revenues associated with the sale of information products derived, in whole or in part, from public marine data, as well as gains in efficiency or productivity derived from an information product or service resulting in whole or in part from marine data (i.e. costs savings, cost avoidance and increased revenues). Further benefits include those received by society in ways that are often easier to identify than to quantify, including particularly improved ocean governance (OECD, 2019[1]).

5.4. Recommendations

… to institutional funders

- *Support the entire marine data value chain:* Public marine data generate benefits in many different sectors of the economy, as shown by the findings presented in this paper. Public agencies aiming to support the development of efficient, publicly-funded data management and archiving systems for users could implement cost-effective governing frameworks supporting the targeted collection of public marine data, avoiding duplication, while taking advantage of new information technologies (e.g. cloud technologies to reduce the costs of data storage and the adoption of APIs for users to link to data automatically);
- *Promote the use and reuse of marine data in policies:* Based on the survey findings, policies that support the development of specific marine/maritime sectors, together with ad-hoc regulations and environmental assessment requirements, lead to the use and reuse of diverse types of public marine datasets much beyond their initial purposes (e.g. policies and regulations of offshore wind industry in the UK contributing to novel public marine data usages, from marine geology to biology). Promoting the usefulness of these diverse marine datasets in different sectors would contribute to make public data use and reuse increase, as a result of broader marine/maritime policies.

… to the marine observing community and data archive & management centres

- *Develop communication strategies that clearly outline how the collection and archiving of marine data are used and reused for many different purposes throughout the ocean economy and beyond.* As shown in the survey, data are used and reused in a great number of diverse value chains (e.g. diverse types of data used to support brand new offshore wind projects). Publicising the existing and successful use and reuse of marine data to various different communities and different sectors could encourage further usages, allowing the societal and commercial potential of archived marine datasets to grow.
- *Better track marine data users:* Increased efforts to track user groups, their downloads and use of the data would help identify associated marketable and social values without contravening the FAIR principles of data findability, accessibility, interoperability, and reusability. This would involve improved identification of data users through simple and, if need be, voluntary registration processes and via regular, voluntary surveys, for both regular and ad-hoc users.
- *Facilitate the use of Application Programming Interfaces*: Take into account the technical needs of data users and developers who are increasingly taking advantage of Application Programming Interfaces (APIs), to allow them to programmatically interact with marine data. This would likely enhance public marine data usage going forward.

… on the next steps

The results of this survey of UK marine data users provide much information on the users of marine data, data flows and value chains, and complements well other valuation initiatives. The next steps in the process of valuing public marine data could be as follows:

- Suitable valuation methodologies would need to be assessed and the specificities of marine data reuse need to be analysed to inform future valuation exercises.

- In addition, new surveys in different parts of the world would contribute to building the knowledge base, discovering and contributing to the understanding value chains in different contexts and cultures.

Annex A. OECD Survey of Marine Data Users

This Annex includes the questionnaire that was used as part of the OECD Survey of Marine Data Users, made available on the UK MEDIN portal and partnering portals at the end of March 2020 until early September 2020.

1. Welcome message

Marine Data Value Chain Survey

The OECD has teamed up with the UK's Marine Environmental Data and Information Network (MEDIN) and the Global Ocean Observing System (GOOS) IOC/UNESCO to improve understanding of the use of marine data made publicly available through specialised data archive/management centres.

The questionnaire you are about to answer has three related objectives:

- Update current understanding of the user communities of public marine data archive/management centres
- Explore the pathways through which public marine data are used and transformed into actionable information
- Lay the foundations for future work in measuring the value of marine data by creating systemised depictions of the use of the data

While the coronavirus pandemic is having extraordinary impacts on the way people and organisations operate throughout the world, we believe the importance of marine data should continue to be highlighted through studies such as this. Your contribution will help inform future ocean policies in the run-up to the United Nations Decade of Ocean Science for Sustainable Development 2021-2030. We hope our analysis of the role of public marine data in society will be useful to you, data archive/management centres and all relevant communities.

Thank you very much in advance for taking the time to complete this questionnaire, which should take you less than ten minutes.

Personal Data Protection Notice for OECD Marine Data Value Chain Survey

The OECD is committed to protecting the personal data it processes, in accordance with its Personal Data Protection Rules.

The OECD Directorate for Science, Technology and Innovation is using this survey to collect personal data, including name, email address, job title, employer/name of organisation, country of employer/organisation and postal code of employer/organisation. The data will be used to identify individual responses to the survey and to enable contact of the respondent, only if permission is given by the respondent.

The personal data we collect will be stored securely by the OECD and retained until the appropriate analysis has been conducted of the survey responses. Only the OECD will have access to your personal data.

Under the Rules, you have rights to access and rectify your personal data, as well as to object to its processing, request erasure, and obtain data portability in certain circumstances. To exercise these rights in connection with this survey, please contact XXX.

2. Basic respondent information

Name:

Email:

Job title:

Employer/name of organisation:

Country of employer/organisation:

Postal code of employer/organisation:

3. Data archive/management centre

Which of the following data archive/management centres directed you towards answering this questionnaire?

() Archaeological Data Service (ADS)

() British Geological Survey (BGS)

() British Oceanographic Data Centre (BODC)

() Centre for Environment, Fisheries and Aquaculture Science (CEFAS)

() DASSH - The Archive for Marine Species and Habitats Data

() Historic Environment Scotland (HES)

() Marine Scotland Science (MSS)

() Marine Environmental Data & Information Network (MEDIN)

() Met Office

() Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW)

() UK Hydrographic Office (UKHO)

() Other ____________________

4. Reason for visiting data archive/management centre

Which of the following options best describes your reason for visiting the data archive/management centre?

() Download/view raw datasets (unprocessed or calibrated data that may have undergone basic quality controls and checking)

() Download/view data products (interpolated, aggregated or derived data from analysis or models)

() Link to data (via API, Web Map Services, Web Feature Services or other)

() Search for data that may or may not already exist

() Other ______________________

What types of data and/or data product have you downloaded, viewed and or linked to from the data archive/management centre recently?

() Administration and dimensions: Administration and dimensions

() Atmosphere: Atmospheric chemistry

() Atmosphere: Meteorology

() Biological oceanography: Other biological measurements

() Biological oceanography: Biota composition

() Biological oceanography: Biota abundance, biomass and diversity

() Biological oceanography: Bacteria and viruses

() Biological oceanography: Birds, mammals and reptiles

() Biological oceanography: Pigments

() Biological oceanography: Phytoplankton and microphytobenthos

() Biological oceanography: Underwater photography

() Biological oceanography: Disease, damage and mortality

() Biological oceanography: Zooplankton

() Biological oceanography: Microzooplankton

() Biological oceanography: Fish

() Biological oceanography: Macroalgae and seagrass

() Chemical oceanography: PCBs and organic micropollutants

() Chemical oceanography: Carbonate system

() Chemical oceanography: Nutrients

() Chemical oceanography: Halocarbons (including freons)

() Chemical oceanography: Other inorganic chemical measurements

() Chemical oceanography: Isotopes

() Chemical oceanography: Other organic chemical measurements

() Chemical oceanography: Carbon, nitrogen and phosphorus

() Chemical oceanography: Fatty acids

() Chemical oceanography: Amino acids

() Chemical oceanography: Metal and metalloid concentrations

() Chemical oceanography: Hydrocarbons

() Chemical oceanography: Dissolved gases() Cross-discipline: Fluxes

() Cross-discipline: Rate measurements (including production, excretion and grazing)

() Cryosphere: Palaeoclimate

() Cryosphere: Cryosphere

() Environment: Pollution

() Environment: Habitat

() Human activities: Transport

() Human activities: Construction and structures

() Human activities: Fisheries

() Human activities: Hydrocarbon extraction

() Human activities: Cables

() Human activities: Energy

() Human activities: Mining

() Human activities: Pipelines

() Human activities: Area Management/Designation

() Human activities: Aquaculture

() Human activities: Tourism

() Human activities: Cultural Heritage

() Human activities: Salt extraction

() Marine geology: Rock and sediment physical properties

() Marine geology: Rock and sediment chemistry

() Marine geology: Geochronology and stratigraphy

() Marine geology: Suspended particulate material

() Marine geology: Sediment pore water chemistry

() Marine geology: Field geophysics

() Marine geology: Geothermal measurements

() Marine geology: Gravity, magnetics and bathymetry

() Marine geology: Rock and sediment sedimentology

() Marine geology: Sedimentation and erosion processes

() Marine geology: Rock and sediment lithology and mineralogy

() Physical oceanography: Currents

() Physical oceanography: Optical properties

() Physical oceanography: Waves

() Physical oceanography: Acoustics

() Physical oceanography: Water column temperature and salinity

() Physical oceanography: Sea level

() Physical oceanography: Other physical oceanographic measurements

() Sonar and seismics: Sonar and seismics

() Terrestrial: Rock and sediment biota

() Terrestrial: Terrestrial

() Other _______________

5. Sector

Which of the following options best describes the sector in which you conduct your activities?

() Academia / research centre

() Consultancy

() Environment agency

() Financial institution

() Government / policy

() Commercial / industry

() Maritime authority

() Non-governmental organisation

() Other ______________________

6. Occupation

Which of the following options best describes your main occupation?

() Archaeologist, historian

() Armed forces professional

() Business services, administration, auditing specialist / manager

() Commercial diver

() Computer information and systems specialist / manager

() Digital, data and technology

() Education – Academic, teaching associate, education officer

() Environmental consultant

() Environmental scientist / engineer

() Fisheries manager

() Fishery worker

() Information specialist

() Marine geomatics specialist

() Marine / naval architect

() Marine resource manager or spatial planner

() Marine scientist (biogeochemistry and ecosystems dynamics)

() Marine scientist (geology and geophysics)

() Marine scientist (hydrographic surveying)

() Marine scientist (marine biology and ecology)

() Marine scientist (marine conservation/environmental protection)

() Marine scientist (oceanography, ocean modelling and forecasting)

() Marine scientist (palaeoceanography)

() Ocean engineer (mechanical, electrical, civil, acoustical and/or chemical engineering)

() Port authority manager

() Port operative, harbour pilot

() Regulator

() Sales, marketing and development manager

() Seafarer

() Student

() Surveyor

() Unexploded ordnance operative

() I download data as part of a hobby

() Other ______________________

7. Industry

If you work in or alongside industry, please select the options that best describe the industry(ies) in or with which your activities take place. You may select the options you deem relevant up to a maximum of three.

If more than three options are relevant, please pick the three that are of the most importance to your activities.

() Marine and coastal tourism

() Marine aquaculture

() Marine fishing

() Marine mining and dredging

() Maritime freight transport

() Maritime manufacturing, repair and installation

() Maritime passenger transport

() Maritime ports and support activities for maritime transport

() Maritime ship, boat and floating structure building

() Naval and search and rescue

() Ocean scientific research and development

() Offshore extraction of crude petroleum and natural gas

() Offshore industry support activities (including surveying)

() Offshore wind and marine renewable energy

() Processing and preserving of marine fish, crustaceans and molluscs

() Other: ______________________

Please answer the following question(s) in accordance with the importance of the industry(ies) selected above to your overall activities. The industry that is the most important to your activities is considered your primary industry. The second most important, your secondary industry. The third is the tertiary industry.

Ensure that you select only one primary industry and, if relevant, one secondary industry and one tertiary industry.

Indicate the importance of XXX to your overall activities:

() It is the primary industry in/with which I work

() It is the secondary industry in/with which I work

() It is the tertiary industry in/with which I work

8. Data usage (I)

Which of the following options best describe the *field(s) in which you apply* the data you download, view and/or link to from the data archive/management centre? Select as many options as you deem relevant up to a maximum of three.

If more than three options are relevant, please pick the three that are of the most importance to your activities.

() Climate science

() Coastal protection

() Conservation

() Defence

() Education

() Food security

() Health

() Marine archaeology

() Marine renewable energy

() Marine science

() Navigation

() Offshore oil and gas

() Offshore wind

() Policy development/marine management

() Search and rescue, safety of life

() Weather and sea state forecasts and predictions

() Other: _________________

Please answer the following question(s) in accordance with the importance the field(s) of application selected above to your overall activities. The field of application that is the most important to your activities is considered your primary field. The second most important, your secondary field. The third is the tertiary field.

Ensure you select only one primary field and, if relevant, one secondary field and one tertiary field.

Indicate the importance of XXX in your fields of application:

() It is the primary field of application

() It is the secondary field of application

() It is the tertiary field of application

9. Data usage (II)

Which of the following options best describe the *action(s) taken* with the data you download, view and/or link to from the data archive/management centre? Select as many options as you deem relevant up to a maximum of three.

If more than three options are relevant, please pick the three that are of the most importance to your activities.

() Analyse policies

() Analyse risk

() Conduct research and development

() Conduct statutory reporting

() Inform coastal planning decisions

() Inform marine planning decisions

() Inform operations

() Manage marine resources

() Raise awareness and education

() Raise finance

() Validate data from elsewhere

() Target investments

() Other ______________________

Please answer the following question(s) in accordance with the importance of the action(s) taken selected above to your overall activities. The action that is the most important to your activities is considered your primary action. The second most important, your secondary action. The third is the tertiary action.

Ensure that you select only one primary action and, if relevant, one secondary action and one tertiary action.

Indicate the importance of XXX in your actions taken:

() It is the primary action taken

() It is the secondary action taken

() It is the tertiary action taken

10. Data usage (III)

Please describe what you do with the data in your own words:

____

____

If you have a document that describes your data usage and you would like to share it, please do so here:

____

If you have a web link (URL) that demonstrates your data usage and you would like to share it, please do so here:

____

Who do you typically share your re-used data and/or data products with?

() Colleagues for collaboration

() Colleagues for other purposes

() General public

() Government advisors

() Relevant data archive/management centres

() Unknown

() Other ___________________

11. Frequency

Which of the following options best describes the frequency of your use of the data you download, view or link to from the data archive/management centre?

() I use the data daily

() I use the data weekly

() I use the data monthly

() I use the data annually

() I use the data every now and then but there is no pattern to my data use

() I have used the data from the data archive/management centre only once or a few times

() Once I have created a dynamic link to the data it will automatically be used

() Other ______________________

12. Commercial purposes

The information requested in this section is aimed at gaining a better understanding of the societal value of public marine data and will not be used in any other way by OECD, MEDIN or GOOS.

Are the data used in the production of a revenue generating product?

() Yes

() No

() Prefer not to say

() Other ______________________

Please describe the product in one or two sentences:

____

____

If yes, please select the sector from which the majority of your customers originate:

() Academia / research centre

() Consultancy

() Environment agency

() Financial institution

() Government

() Industry

() Maritime authority

() NGO

() Prefer not to say

() Other ______________________

If you have a document that describes your commercial data usage and you would like to share it, please do so here:

____

If you have a web link (URL) that demonstrates your commercial data usage and you would like to share it, please do so here:

____

13. Alternative sources of data

If the data archive/management centre did not exist, what would you do?

() Collect the data in the field

() Discontinue my tasks

() Duplicate efforts to create or derive the data

() Make decisions based on available next-best data (not optimal)

() Make direct request to the organisation to obtain the data

() Purchase the data privately

() Use another public data archive/management centre

() Use data modelled by myself

() Other ______________________

14. Open ended explanation of benefits

Please briefly describe how the data you download, view and/or link to from the data archive/management centre benefit your activities.

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If you have a document that describes how the data benefit your activities and you would like to share it, please do so here:

____

If you have a web link (URL) that demonstrates how the data benefit your activities and you would like to share it, please do so here:

____

15. Other relevant contributions

If you have any additional points to raise regarding the societal value of public marine data, please leave your comments here:

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If you have a document that describes your thoughts on the societal value of public marine data and you would like to share it, please do so here:

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If you have a web link (URL) that demonstrates your thoughts on the societal value of public marine data and you would like to share it, please do so here:

____

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16. Marine data use and COVID-19

The coronavirus pandemic is having extraordinary impacts on the way people and organisations operate throughout the world. Such disruption is unavoidable as the need to continue fighting the pandemic is clear. The OECD is compiling data, analysis and recommendations on a range of topics to address the emerging health, economic and societal crisis, facilitate co-ordination, and contribute to the necessary global action when confronting this enormous collective challenge. More information on such efforts can be found here: http://www.oecd.org/coronavirus.

We recognise that these are far from normal times and that your uses of marine data may change as a result. The following questions aim to provide us with information that will allow recognition of the potential effects of the coronavirus pandemic in our analysis.

How do you expect changes caused by the coronavirus pandemic to impact the volume of marine data and/or data products you download from the repository?

() I will download lower volumes of data

() I will download higher volumes of data

() I will download the same volumes of data

() Other: ____________________

How do you expect changes caused by the coronavirus pandemic to impact your uses of marine data and/or data products?

() It will encourage more uses

() It will encourage new uses

() It will encourage less uses

() My uses will remain the same

() Other: ____________________

In a few sentences, please describe in your own words the types of impacts (if any) you expect the coronavirus pandemic to have on your activities:

____

____

If you have a document that describes how the coronavirus pandemic may impact your activities and you would like to share it, please do so here:

____

If you have a web link (URL) that demonstrates how the coronavirus pandemic may impact your activities and you would like to share it, please do so here:

____

17. Permission to contact

The OECD may wish to contact you in order to conduct further research into the uses of public marine data. Do you agree to being contacted?

() I agree

() I do not agree

How would you prefer to be contacted?

() Email ____________________

() Telephone ____________________

Would you like to be kept informed of the release of analysis of the results of this questionnaire?

The OECD aims to release a report in late autumn 2020 that will be accessible via the OECD, MEDIN and participating data archive/management centres.

() Yes

() No

18. Final message

You have reached the end of the questionnaire

Thank you very much for completing the survey and contributing to a better understanding of the uses of public marine data

If you have any further questions or comments regarding the survey, the marine data value chain project or the OECD's activities surrounding the ocean economy, please send an email to chrystyna.harpluk@oecd.org.

Annex B. Description of the SeaDataNet disciplines (P08) and parameters (P03) used in the survey

SeaDataNet develops vocabularies as well as standards for data and metadata in cooperation with the different ocean scientific communities. Some SeaDataNet vocabularies were used to draft the OECD marine data survey presented in this paper. The following table presents detailed descriptions of disciplines (P08) and parameters (P03) that were used, and which may used again in future surveys.

The controlled vocabulary published by SeaDataNet is not hierarchical in the sense that each P08 discipline contains a unique set of P03 parameters (e.g. the P03 parameter 'B007 Biota Composition' falls under both the 'DS01 Biological Oceanography' and 'DS02 Chemical Oceanography' P08 disciplines).

For the purposes of the statistics produced from the results of the survey, each parameter that appears in more than one discipline has been assigned to the discipline in which it is most likely to be used. For example, the P03 parameter 'H003 Palaeoclimate' is counted under the P08 discipline 'DS10 Environment' only.

P08 code	P08 description	P08 definition	P03 code	P03 description	P03 definition
DS07	Administration and dimensions	Parameters related to spatial and temporal co-ordinates, entity referencing (eg record numbering and keys) and access control	Z005	Administration and dimensions	This APG is primarily intended for parameters that specify the dimensions: x, y (e.g. latitude, longitude) z (e.g. height above sea level/sea floor, depth/pressure) t (e.g. date/time, elapsed time) However, there are other parameters, such as general purpose quality control flags, sequence numbers, platform orientation (heading)/velocity, sampling duration/quantity (e.g. volume filtered) that have been included in the BODC dictionary mapping.
DS05	Atmosphere	The atmospheric sciences domain	M005	Atmospheric chemistry	Parameters quantifying and characterising the solid, liquid and gaseous materials that make up the Earth's atmosphere
			M010	Meteorology	Physical phenomena and properties of the atmosphere including air temperature, air pressure, humidity, precipitation, wind velocity and radiation.
DS01	Biological oceanography	The biological oceanographic science domain	B005	Bacteria and viruses	This group incorporates all state variables pertaining to bacteria (Kingdom Monera)and viruses. Note that Monera includes both Phylum Bacteria and Phylum Cyanophycota (cyanobacteria but sometimes called blue-green algae). Most parameters in this group express the abundance, either as cell counts or biomass, of various types of bacteria or viruses. However, the group also includes

					parameters that describe any other property of these entities that are not rates or fluxes . Examples include cell size, cell volume and the proportion of the population associated with the particulate phase.
			B070	Biota abundance, biomass and diversity	All parameters of any dimensionality (per unit volume, area or simply counts) quantifying the numbers, mass or diversity (species variation) of biota in water bodies, sediment or the atmosphere.
			B007	Biota composition	This group contains all parameters relating to the composition of organisms or their constituent parts. It may include any analytical measurements on biological material, but is specifically designed for heavy metal and organic contaminant biota pollution monitoring data.
			B015	Birds, mammals and reptiles	This group incorporates all variables pertaining to birds, mammals and reptiles, including abundance, biomass, biological function and state of health.
			B060	Disease, damage and mortality	Parameters pertaining to all types of diseases, infections, poisonings and physical damage in any type of biota.
			B020	Fish	This group incorporates all state variables pertaining to fish, such as abundance, biomass and fisheries data.
			B050	Habitat	Grouping of parameters that characterise, spatially define, label or classify places where organisms are found.
			B055	Macroalgae and seagrass	Parameters pertaining to plants in the taxonomic groups Rhodophycota, Chromphycota and Chlorophycota (seaweeds/macroalgae) and Charophyta plus Anthophyta (seagrass)
			B025	Microzooplankton	This group incorporates all state variables pertaining to microzooplankton, defined as heterotrophic organisms smaller than 200 microns in length. The term covers organisms sometimes referred to as picozooplankton or nanozooplankton. Most parameters express the abundance, either as cell counts or biomass, of various types of microzooplankton, but may include other properties such as cell volume. Rates (including grazing parameters) and fluxes are not included here (see Rates and Fluxes APGs).
			B027	Other biological measurements	This is a 'safety net' category to cover biological parameters that cannot be mapped to other Agreed Parameter Groups. It should be regarded as a transitional grouping: if a significant number of related parameters map to this group then the creation of an additional group should be discussed and agreed.
			B030	Phytoplankton and microphytobenthos	Parameters related to autotrophic organisms smaller than 200 microns that are free-floating in water bodies, live in sediment or on the seabed.

			B035	Pigments	This group incorporates plant pigment concentration parameters and uncalibrated readings from instruments that make in-situ pigment measurements, such as fluorometer voltages. The grouping includes measurements on pigments in the particulate phase of the water column (expressed as pigment mass per unit volume/mass of water), pigments in sediment (expressed as pigment mass per unit mass or volume of sediment) and zooplankton gut pigment contents (expressed as pigment mass per individual).
			UWPH	Underwater photography	Still or video digital images taken below the surface of the water column
			B045	Zooplankton	This group incorporates all state variables pertaining to zooplankton, which are defined for the purposes of this grouping as any heterotrophic organisms in the water column that are not mammals, reptiles or fish. Most parameters in this group express the abundance, either as cell counts or biomass, of various types of zooplankton. However, the group also includes parameters that describe any other property of these entities that are not rates or fluxes , such as the concentrations of faecal pellets or eggs in the water column or sediment.
DS02	Chemical oceanography	The chemical oceanographic science domain	C003	Amino acids	This group contains parameters pertaining to amino acid concentrations. Amino acids are defined as carboxylic acids with an amino group at the alpha position. The grouping covers concentrations of these compounds in the water column (mass of amino acid per unit mass/volume of water) or their content in sediment or suspended particulate matter. The grouping does not include amino acid fluxes or rate variables, such as bacterial production by leucine uptake.
			C005	Carbon, nitrogen and phosphorus	This group contains the state variable parameters pertaining to carbon, nitrogen and phosphorus that do not obviously belong in other groupings.
			C010	Carbonate system	This group incorporates the state variables that describe the concentration of dissolved inorganic carbon and the status of the equilibrium between this and the atmospheric carbon dioxide concentration. These are: Carbon dioxide partial pressure/fugacity. Total alkalinity. pH Dissolved inorganic carbon (TCO 2) The group also includes parameters that are essential for the interpretation of the data, such as the temperature at which a parameter was collected or to which it has been recalculated.

			C015	Dissolved gases	This group incorporates dissolved gas concentrations and/or saturations, excluding: Gases that are incorporated into the water column through chemical reaction and quantified as the products of the reaction, such as ammonia and carbon dioxide. Gases that belong to other chemical-type APGs. For example, methane parameters are placed in the Hydrocarbons APG and not Dissolved Gases.
			C017	Fatty acids	This group incorporates the parameters relating to the fatty acid content of sediment or suspended particulate material. Contents are expressed either as 'concentrations' (SPM fatty acid per unit volume of water) or 'contents' (quantity of fatty acid per unit mass of sediment or SPM). Fatty acids are considered as the naturally occurring continuous chain, saturated and unsaturated aliphatic acids. In their ester form these are the constituents of the fats, waxes and oils of plants and animals. Simpler carboxylic acids with an alkyl or alkenyl group, sometimes loosely termed 'fatty acids' are not included.
			C020	Halocarbons (including freons)	Parameters concerning all compounds of carbon covalently bonded to and one or members of the halogen group (fluorine, chlorine, bromine or iodine) but with no other functional groups. It includes naturally generated compounds (usually short-chain haloalkanes and haloalkenes), man-made freons and contaminants such as organochlorine pesticides.
			C025	Hydrocarbons	This group contains parameter codes describing the concentrations of the compounds of carbon and hydrogen. All compounds conforming to this definition are placed in this APG, including aromatic compounds, even polycyclic aromatic hydrocarbons traditionally categorised as 'pollutants'. This is to circumvent problems deciding which hydrocarbons are pollutants and which are not.
			C030	Isotopes	This group contains parameter codes relating to the abundance of both radioactive and stable isotopes. All types of substrate are included - water, SPM, sediment and biological material.
			C035	Metal and metalloid concentrations	Parameters pertaining to metal and trace metalloid (i.e. excluding Si) concentrations in any material.
			C040	Nutrients	This group contains parameter codes describing the concentrations of the substances that provide the essential basic elements - nitrogen, phosphorus and silicon - to the phytoplankton. The species covered are: Nitrogen - nitrate, nitrite, ammonium and urea. Phosphorus - orthophosphate Silicon - hydrosilicic acid, commonly termed 'silicate'. The grouping also covers uncalibrated analytical or in-situ instrument outputs, such as monochromatic optical absorbances at the appropriate wavelengths

					for nutrient determination.
			C045	Other inorganic chemical measurements	This is a 'safety net' category to cover inorganic chemical parameters that cannot be mapped to other Agreed Parameter Groups. It should be regarded as a transitional grouping: if a significant number of related parameters map to this group then the creation of an additional group should be discussed and agreed.
			C050	Other organic chemical measurements	This is a 'safety net' category to cover organic chemical parameters that cannot be mapped to other Agreed Parameter Groups. It should be regarded as a transitional grouping: if a significant number of related parameters map to this group then the creation of an additional group should be discussed and agreed.
			C055	PCBs and organic micropollutants	This group is designed to bring together parameters pertaining to concentrations of extremely toxic organic chemicals in air, water, SPM, sediment or biological material.
DS06	Cross-discipline	No specific association with an identified domain	O005	Fluxes	This group contains parameter codes that relate to the rate of transfer of material across real or virtual interfaces.
			O010	Rate measurements (including production, excretion and grazing)	This group contains parameter codes that relate to the rate of change of quantity of any chemical species or biological entity. Rates mey be the result of biological (e.g. production), chemical (e.g. photochemical degradation) or biogeochemical (e.g. particulate phase metal uptake rate) processes.
DS09	Cryosphere	The cryosphere science domain, including ice on both land and sea	M015	Cryosphere	This group incorporates all parameters pertaining to frozen precipitation, lying snow and ice, permafrost, icebergs, glaciers and ice caps.
DS10	Environment	The domain documenting the habitat (physical, biological or chemical conditions) surrounding an organism or a group of organisms, or factors affecting any part of the earth ecosystem past and present.	H002	Construction and structures	Parameters describing the nature and impact of coastal and offshore man-made objects and the process of creating them.
			H003	Palaeoclimate	Measurements and parameterisations from which the climatic conditions in the recent or geological past may be determined or described.
			H001	Pollution	Parameters describing the abundance, nature and impact of material added to the environment by the activities of man.
DS12	Human activities	The domain documenting the activities of man that have an effect on the Earth System.	H006	Aquaculture	Datasets related to the process or industry of farming aquatic animal and plants.
			H007	Area Management /Designation	Datasets related to the process of managing aquatic and coastal environments.
			H008	Cables	Datasets related to the process or industry of deploying and maintaining communication and power cables.
			H009	Cultural Heritage	Datasets related to the process of managing cultural and historical artifacts.

			H010	Energy	Datasets related to the process or industry of electrical power generation.
			H004	Fisheries	Parameters related to any aspect of the taking of water-living fauna from the wild
			H011	Hydrocarbon extraction	Datasets related to the process or industry of locating and extracting hydrocarbon compounds from underground sources.
			H012	Mining	Datasets related to the process or industry of locating and extracting coal or other minerals.
			H013	Pipelines	Datasets related to the process or industry of deploying and maintaining pipelines.
			H014	Salt extraction	Datasets related to the process or industry of extracting salt from saltwater.
			H015	Tourism	Datasets related to the process or industry of tourism including activities and facilities or installations.
			H016	Transport	Datasets related to the process or industry of transport including activities and facilities or installations.
DS04	Marine geology	The marine geological science domain	GPYS	Field geophysics	In-situ measurements of physical phenomena designed to elucidate the composition and structure of underlying geological units
			G030	Geochronology and stratigraphy	Parameters pertaining to the absolute and stratigraphic age of rocks (including speleotherms) and unlithified sediment.
			GTHM	Geothermal measurements	Parameters pertaining to the distribution of the degree of hotness in geologic units (including bodies of unconsolidated sediment), heat transfer in the Earth and the thermal properties of rocks, minerals and sediments.
			G005	Gravity, magnetics and bathymetry	Parameters related to the strength and characteristics of the Earth's magnetic and gravity fields and the spatial variation in water body depth.
			G055	Rock and sediment biota	Parameters pertaining to flora, fauna and their fossil remains in rocks and unlithified sediment. Includes zoobenthos, phytobenthos and palaeontology.
			G035	Rock and sediment chemistry	Parameters pertaining to the chemistry (including isotopic composition) of rocks (including speleotherms) and unlithified sediment.
			G045	Rock and sediment lithology and mineralogy	Parameters pertaining to the petrological characterisation and component minerals of rocks (including speleotherms) and unlithified sediment.
			G040	Rock and sediment physical properties	Parameters pertaining to the physical properties of rocks (including speleotherms) and unlithified sediment.
			GSED	Rock and sediment sedimentology	Parameters pertaining to the sedimentological characterisation (e.g. structure, formation) of rocks (including speleothems) and unlithified sediment
			G050	Sediment pore water chemistry	Parameters pertaining to the chemistry of the interstitial pore waters in unlithified sediments.

			G060	Sedimentation and erosion processes	Parameters pertaining to the removal and deposition of unlithified sediments.
			G012	Sonar and seismics	Parameters associated with determination of sub-floor structure based on the propogation of acoustic energy and acoustic imaging of the sea floor.
			G015	Suspended particulate material	Parameters pertaining to material in suspension within water bodies.
DS03	Physical oceanography	The physical oceanographic science domain	D005	Acoustics	This group contains parameter codes relating to the propagation of sound through seawater, such as signal amplitude, noise, signal return, travel time and sound velocity.
			D030	Currents	This APG contains all parameters pertaining to the measurement of: Eulerian currents Lagrangian currents (except drifter position) Vertical currents River flow velocity
			D015	Optical properties	This APG contains parameters pertaining to the optical properties of seawater.
			D020	Other physical oceanographic measurements	This is a 'safety net' category to cover physical oceanographic parameters that cannot be mapped to other Agreed Parameter Groups. It should be regarded as a transitional grouping: if a significant number of related parameters map to this group then the creation of an additional group should be discussed and agreed.
			D032	Sea level	This APG contains all parameters pertaining to the measurement of: Sea level relative to a terrestrial datum Water column height at a fixed location
			D025	Water column temperature and salinity	This APG includes the parameters associated with the in-situ measurement of water column temperature (including potential temperature) and salinity (including conductivity). Parameters derived from either temperature or salinity (but not temperature AND salinity), such as temperature gradient or temperature variance, are also included.
			D034	Waves	This APG contains all parameters pertaining to the measurement of: Wave height Wave period Wave direction Wave energy spectra
DS08	Terrestrial	The terrestrial science domain	T001	Terrestrial	This APG contains parameters related to the characterisation of the land surface. These are usually, but not exclusively, determined by remote sensing techniques. Data types falling within the scope of the group are: Land surface temperature Land vegetation Vertical currents Terrestrial water content Terrestrial mapping and the geo-location of features such as coastlines

Source: SeaDataNet (2021) *BODC webservices V2 (Libraries) CL12* (accessed 30 April 2021)

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