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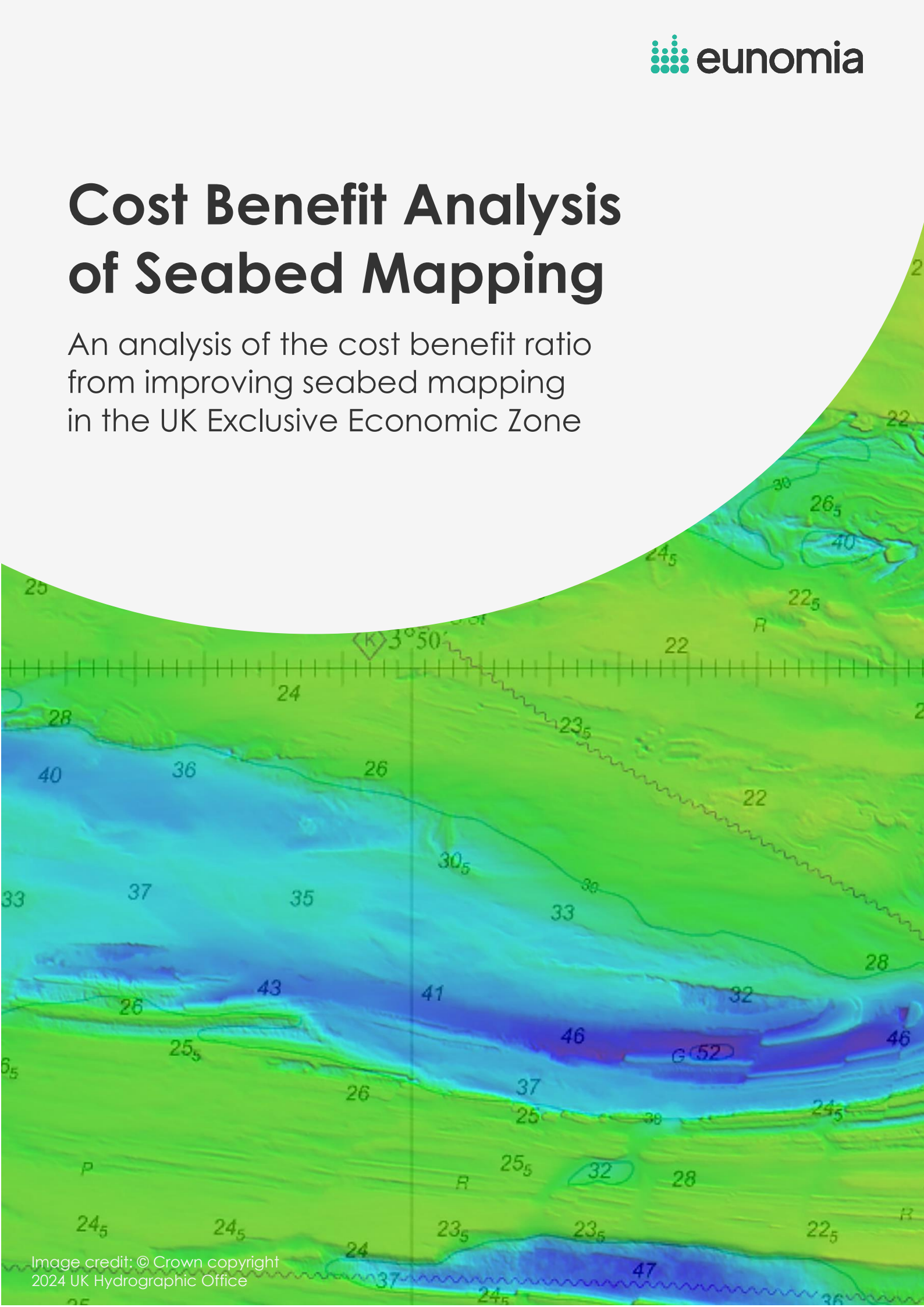
Cost Benefit Analysis of Seabed Mapping

An analysis of the cost benefit ratio from improving seabed mapping in the UK Exclusive Economic Zone



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Executive Summary

Introduction

The UK Hydrographic Office (UKHO) commissioned Eunomia Research & Consulting (Eunomia) to undertake an independent cost benefit analysis of seabed mapping in the UK Exclusive Economic Zone (EEZ) around the British Isles. This report defines the cost benefit relationship to the UK economy of seabed mapping, by deriving an indicative ratio showing the value of benefit returned on investment in seabed mapping. The report also provides a template for equivalent studies in nations for which the UKHO is the Primary Charting Authority.

The UK is a maritime nation and the marine environment is an essential and dynamic element of the UK's economy, therefore understanding the UK's marine environment is crucial for realising and managing its environmental, economic and social value. Seabed mapping enhances the understanding of the seafloor and contributes to planning and decision making in maritime sectors; almost all activity in the marine environment is supported by marine geospatial data.

Despite the importance of seabed mapping, only 27% of the UK EEZ is mapped with high confidence to the latest modern internationally agreed standards, falling to just 2% when including the UK Overseas Territories. Current data availability is not always sufficient for government decision making. Undertaking local mapping activities without consistent collation at the national level is considered a significant obstacle to the sustainable and productive management of the sea and seabed resources.

There is currently scarce evidence of the value that seabed mapping activities bring to the UK economy. Assigning a monetary value to seabed mapping is important to allow for a complete assessment of the full economic value of this activity, to aid evidence-based decision making on the resources that should be dedicated to seabed mapping activities. This report presents analysis on the market and non-market impacts attributed to seabed mapping and leverages the quantitative and qualitative insights gathered through the research and analysis to present the key outputs and findings from the research.

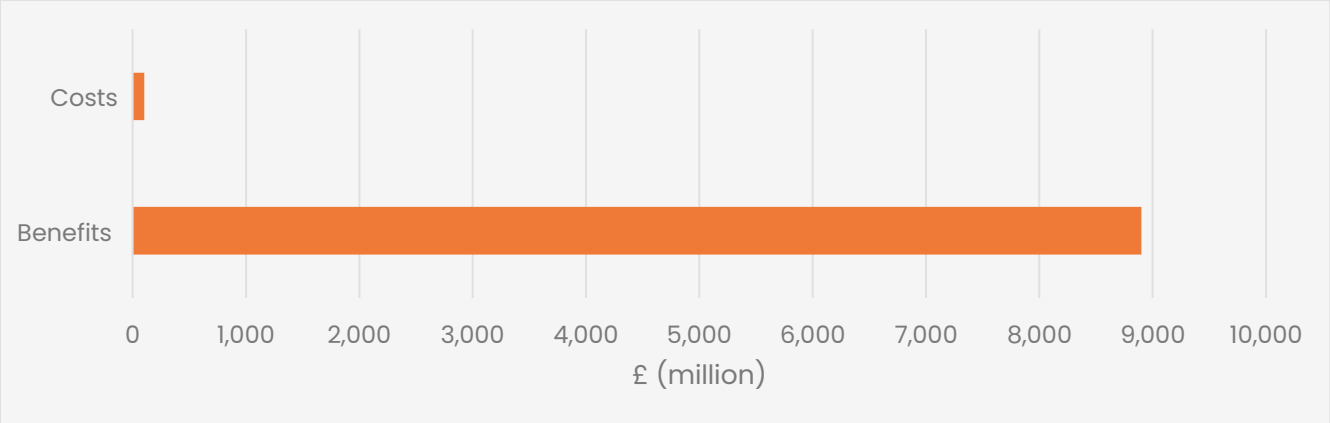
Approach

The approach to undertaking the cost benefit analysis on behalf of the UKHO was structured to deliver a robust analysis of the financial costs and benefits associated with seabed mapping. Firstly, Eunomia established the sectors that utilise seabed mapping for inclusion in the research. This was followed by comprehensive secondary research, to determine the GVA of these maritime sectors and to review pre-existing literature on similar cost benefit studies conducted for other nations, to inform the methodology and provide benchmarking for comparison. In the second phase of research key relevant organisations were identified, including trade associations and businesses in each sector, to be engaged with for primary research into the attribution of seabed mapping to the operations and economic growth of each sector. Finally, economic modelling and quantitative analysis was undertaken to derive a Cost Benefit Analysis (CBA) ratio of return on investment that seabed mapping brings to the UK economy.

Results

The total value of benefits is calculated to be **£8,901 million**. The expenditure invested in seabed mapping each year is estimated to be **£103 million**. This generates an indicative cost benefit ratio of **86:1** – or £86 benefits realised for every £1 spent on seabed mapping, as demonstrated in Figure E1.

Figure E1: Cost benefit ratio of costs and benefits of seabed mapping



The value that is attributed to each sector in the cost-benefit analysis is displayed in Table E1 (overleaf). These values were determined by calculating the 2023 GVA of each sector (or estimated value for the non-market sectors) and applying a suitable attribution factor. It is estimated that 97% of the value derived from seabed mapping is from market sectors (with offshore energy and shipping, trade and ports being the most significant contributors), with 3% derived from non-market sectors. It should be noted that the value of the marine environment in terms of the ecosystem services that it provides is extensive, but only a small proportion of this value can be attributed to or optimised by seabed mapping, hence the market impacts are significantly greater.

There is significant uncertainty in this figure due to the lack of publicly available data on public and private sector spend, and the inherent uncertainty in determining the proportion of each sector's GVA or value that is attributable to seabed mapping. Moreover, this cost benefit ratio figure presents an average for all seabed mapping activities across the UK EEZ, whereas in reality the manifestation of this ratio will be geographically and temporally variable. Nevertheless, the results of this analysis clearly demonstrate the significant economic and environmental benefits that could be realised through improving seabed mapping coverage to modern standards across the UK EEZ. In addition to the values displayed overleaf, there are also cascading benefits that are 'unlocked' through seabed mapping activities (such as the global trade facilitated through shipping and ports). In acknowledgement of the uncertainty in the calculation of benefits, the ratio of benefits to costs was also calculated under a 'worst case' scenario, using the highest estimate of costs and the lowest estimate of benefits. The result was that the ratio decreases to £33 in benefits for every £1 spent on seabed mapping; even under the most conservative estimate the remains positive.

The stakeholder engagement with seabed mapping data collectors and users also identified key themes for consideration relating to optimisation of the UK's seabed mapping data and capabilities. Investment in seabed mapping would be maximised if accompanied by developments relating to standardised quality measures and mapping specifications, growing the capability and capacity of the domestic seabed mapping and survey industry, greater sharing of seabed mapping data between and within public and private sector entities, and a focus on mapping coastal and maritime areas where market benefits are yet to be realised. Undertaking regular evaluation of the costs and benefits of improved mapping is recommended to account for evolving seabed mapping technologies and for the value generated by emerging sectors.

Table E1: Value of market and non-market impacts included in the cost benefit analysis

Sector / impact	Market or non-market impact	Value (£m, 2023 prices)
Offshore energy	Market	3,576
Shipping, trade and ports	Market	3,129
Telecommunications	Market	591
Marine defence	Market	545
Coastal leisure and tourism	Market	396
Environmental conservation and protection	Non-market	224
Aggregates and mineral extraction	Market	219
Dredging	Market	89
Fishing and aquaculture	Market	85
Cost of avoiding oil spills	Non-market	45
Compliance with legislation	Non-market	1.2
Cost of avoiding marine incidents	Non-market	0.07
	Total	**8,901**

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Acronyms

Acronym	Definition
APPG	All-Party Parliamentary Group
CBA	Cost Benefit Analysis
CEBR	Centre for Economics and Business Research
CHP	Civil Hydrography Programme
EEZ	Exclusive Economic Zone
EGSS	Environmental Goods and Services Sector
FTE	Full-time equivalent
GDP	Gross Domestic Product
GVA	Gross Value Added
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
LCREE	Low Carbon and Renewable Energy Economy
MCA	Maritime and Coastguard Agency
MEDIN	Marine Environmental Data and Information Network
MPA	Marine Protected Area
NNRCMP	National Network of Regional Coastal Monitoring Programmes
ONS	Office for National Statistics
PCA	Primary Charting Authority
SOLAS	(International Convention for the) Safety of Life at Sea
UK	United Kingdom
UKHO	UK Hydrographic Office
UNCLOS	United Nations Convention on the Law of the Sea

1.0 Introduction and context

1.1 Introduction

The United Kingdom (UK) is a maritime nation and the marine environment is an essential and dynamic element of the UK's economy. The maritime sector is estimated to generate over £55 billion annually in business turnover for the UK, contributing £18.7 billion in Gross Value Added (GVA[1]) and supporting approximately 227,100 British jobs.[2] Approximately 95% of all UK imports and exports (by volume) are transported by sea, and almost all data entering and leaving the UK travels by subsea cable.[3] The sector's substantial macroeconomic impacts on turnover, GVA, and employment highlight its vital role in the nation's economic success, and enabling further growth and productivity of the maritime industry remains important for the UK's future economic trajectory. The global use of marine resources continues to change in response to shifting circumstances (including rising populations, a changing climate and rapidly evolving technologies). Hence having a deep understanding of the marine environment to ensure its sustainable use is critical.

The UK's marine estate, including Overseas Territories and Crown Dependencies, is the fifth largest in the world.[4] Understanding the UK's marine environment is crucial for realising and managing its environmental, economic and social value. Seabed mapping enhances the understanding of the seafloor and contributes to planning and decision making in maritime sectors; almost all activity in the marine environment (including commercial fishing, offshore energy generation and tourism) is supported by marine geospatial data.

Seabed mapping is the activity of surveying the shape and composition of the seabed using a variety of platforms, such as ships, underwater vehicles, aircraft, satellites and deep-tow equipment. The seabed can be highly dynamic and contains many hidden features, such as shipwrecks, so being able to visualise the seabed is important for safe navigation and the use and protection of the seabed. The type of mapping conducted, and the platform used, depends on various factors, including geophysical properties and the aims of the mapping exercise. For example, bathymetric mapping is conducted to understand the depth and terrain of the seafloor and is commonly used for safe navigation. Seabed mapping provides information on the features of the seabed, including the distribution of habitats, resource availability for extraction, and it can also show indicators of environmental change.

Despite the importance of seabed mapping, only 27% of the UK Exclusive Economic Zone (EEZ) is mapped with high confidence to the latest modern internationally agreed standards, falling to just 2% when including the UK Overseas Territories.[5] Current data availability is not always sufficient for government decision making. For example, the UK's Marine Conservation Zones (MCZs) were initially identified in three stages based on 'best available data', but were only officially designated following the production of new seabed maps to confirm the presence of seabed habitats.[6] Surveys in the UK EEZ are undertaken by a number of public and private sector bodies and it is anticipated that mapping 100% of the UK seabed would take decades if seabed mapping activities continued at the current rate.[7]

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[1] GVA is considered the best way to represent a sector's economic contribution to the economy.
[2] Maritime UK, 2022. *State of the Maritime Nation*. Available at: https://www.maritimeuk.org/state-of-the-maritime-nation/.
[3] UK Board of Trade, 2022. *Embracing the Ocean*. Available at: https://assets.publishing.service.gov.uk/media/623085988fa8f56c2614da97/board-of-trade-paper-maritime-trade-embracing-the-ocean.pdf
[4] HM Government, 2022. *National Strategy for Maritime Security*. Available at: https://assets.publishing.service.gov.uk/media/62fcbf748fa8f504bd84581f/national-strategy-for-maritime-security-print-version.pdf
[5] UKHO, 2024. *The Role of Seabed Mapping in Ocean Science*. Available at: https://www.gov.uk/government/news/the-role-of-seabed-mapping-in-ocean-science#:~:text=He%20also%20reminded%20attendees%20that,including%20the%20UK%20Overseas%20Territories.
[6] DEFRA, 2016. *Marine Conservations Zones: Update*. Available at: https://assets.publishing.service.gov.uk/media/5a7f33aced915d74e33f4f5c/mcz-update-jan-2016.pdf
[7] CEFAS and ABP MER, 2010. *ME5408: Marine Survey Needs to Underpin Defra Policy - Final Report*. Available at: http://www.oceandtm.com/ME5408_Marine_Survey_Needs_Final_Report.pdf.

Mapping of the seabed and its conditions with modern methods is seen, in international research studies, as one of the key factors for the efficient management and exploitation of this part of the natural ecosystem.[8] Undertaking local mapping activities without consistent collation at the national level is considered a significant obstacle to the sustainable and productive management of the sea and seabed resources.[9] However, as the value of geospatial data is not always accrued directly, there has been a risk of underinvestment in geospatial technology and activities.[10]

In June 2022, the UK Hydrographic Office (UKHO) administered the creation of the UK Centre for Seabed Mapping (UK CSM) to address data collaboration, standards, accessibility and collection. The UK CSM is comprised of public sector organisations which share an interest in optimising the UK's national maritime assets for the security and prosperity of the UK.[11] This represents an important step towards a more cohesive approach towards the collection and maintenance of seabed mapping data and further promoting best practice already in place with some organisational partnerships.

1.2 Research objectives

Despite the importance of seabed mapping, there is currently scarce evidence of the value that the mapping activities bring to the UK economy. Assigning a monetary value to seabed mapping is important to allow for a complete assessment of the full economic value of this activity, to be used to aid evidence-based decision making on the resources that should be dedicated to seabed mapping activities. The UKHO therefore commissioned Eunomia Research & Consulting (Eunomia) to undertake an independent financial cost benefit analysis of seabed mapping in the UK EEZ around the British Isles.

The specific objectives are:

1) To analyse and evaluate the financial cost benefit relationship to the UK economy of the mapping of the UK EEZ around the British Isles, by deriving an indicative ratio showing the value of benefit returned on investment in seabed mapping; and,

2) Provide a template for similar studies in states for which the UK Hydrographic Office is the Primary Charting Authority, including the UK Overseas Territories, Crown Dependencies and other coastal nations. This is described in A.2.0.

In order to deliver these research objectives, Eunomia has undertaken comprehensive data collection, economic modelling, and quantitative analysis to derive indicative return on investment ratios.

This report leverages the quantitative and qualitative insights gathered through the research and analysis to present the key outputs and findings. The report is structured as follows:

- **Section 2.0** presents the methodology followed throughout this research, which included a literature review, stakeholder engagement and analysis and modelling.

- **Section 3.0** presents an overview of seabed mapping activity.

- **Section 5.0** presents analysis on the non-market impacts attributed to seabed mapping.

[8] OECD, 2016. *The Ocean Economy in 2030.* Available at: https://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm
[9] Mapping European Seabed Habitats, 2008. *MESH Guide to Habitat Mapping: A Synopsis.* Available at: https://seabedhabitats.org/research/mesh/
[10] Frontier Economics, 2020. *Geospatial Data Market Study: Report for the Geospatial Commission.* Available at: https://www.frontier-economics.com/media/4340/geospatial-data-market-study.pdf
[11] Admiralty, n.d. *What is the UK Centre for Seabed Mapping (UK CSM)?* Available at: https://www.admiralty.co.uk/uk-centre-for-seabed-mapping

- **Section 5.0** presents analysis on the market impacts generated by seabed mapping.
- **Section 6.0** presents the results of the cost benefit analysis.
- **Section 0** presents the conclusions.

2.0 Methodology

The approach to undertaking the research was structured to deliver a robust analysis of the financial costs and benefits associated with mapping the UK EEZ around the British Isles. The method consisted of:

- Establishing sectors that utilise seabed mapping for inclusion in the research, in **Section 2.1**;
- A literature review to determine the GVA of maritime sectors, described in **Section 2.2**;
- Primary research via stakeholder interviews to understand the contribution of seabed mapping to a range of prioritised sectors, described in **Section 2.3**;
- Economic modelling to ascertain the Cost Benefit Analysis (CBA) ratio of return on investment that seabed mapping brings to the UK economy. Details on this method are presented in **Section 2.4**.

The economic impact of seabed mapping can be separated into two parts:

- **Costs of seabed mapping**. This relates to the result of economic activities within industries producing seabed mapping data.
- **Benefits of seabed mapping**. This includes all of the value added associated with using seabed mapping data. These benefits can take the form of market and non-market impacts. The extent to which seabed mapping yields market impacts (i.e., enabling the economic growth of a sector) depends on the use of seabed mapping in operations – this is explored more in Section 2.4.3. Non-market impacts do not have a clearly defined market based economic value, but instead are associated with intangible benefits like environmental protection and maritime safety. These are explored more in **Section** Error! Reference source not found..

2.1 Activities within scope of the assessment

The list of sectors included in the analysis is as follows:

- Environmental conservation and protection
- Climate change
- Shipping, trade and ports
- Offshore energy, comprising oil and gas and renewable energy
- Coastal leisure and tourism
- Defence
- Telecommunications
- Fishing and aquaculture
- Aggregates and mineral extraction
- Dredging

For some of these sectors, the maritime aspects of the activity may be combined with activities which also take place on land within the literature and data sources. For example, the economic contribution of offshore wind is not presented separately to other energy generation activity that solely takes place on land (e.g. gas fired power stations). Thus, the datasets are apportioned to ensure that only maritime activity is included in the assessment.

There is a range of emerging maritime sectors that utilise a range of seabed mapping outputs that are likely to contribute to the UK's marine economy in the future. According to Eurostat data, the EU blue economy was valued at a GVA of €171 billion in 2021, a growth of 35% since 2020.[12] Another report predicted the global ocean economy would double in size between 2016 and 2030, up to a GVA of $3 trillion.[13] The GVA of some marine sectors like aquaculture, offshore wind and port activities is set to grow faster than the world economy.[14] There are also a range of marine sectors that are currently nascent but expected to grow significantly in the future – as their potential GVA is not fully apparent and cannot yet be accurately quantified, the value of these sectors is not captured in this cost benefit assessment. These sectors include:

- Geological **offshore storage of CO_2** in saline aquifers and depleted oil and gas reservoirs. Greenhouse gas removal technologies (such as direct air carbon capture and storage) continue to develop in technical feasibility, and the anticipated role of these technologies in future climate change mitigation pathways continues to grow. CO_2 captured from hard-to-abate industrial processes is transported and stored offshore (often utilising existing oil and gas industry infrastructure). The UK intends to capture and store between 20 and 30 million tonnes of CO_2 per year by 2030, and there are 27 CO_2 appraisal and storage licences on the UK Continental Shelf.[15] Seabed mapping is and will continue to be used in identifying suitable storage sites and appropriate locations for accompanying infrastructure (ports, subsea pipelines etc.) in addition to monitoring existing infrastructure and storage sites for CO_2 leakage.

- The **development and protection of blue carbon**. Blue carbon refers to carbon held within seabed sediments and marine habitats such as saltmarsh, seagrass and kelp.[16] The role of the ocean as a vital carbon sink is well understood and is discussed in Section 0; however, the cultivation of blue carbon sequestration opportunities (for example, the Essex Seagrass Project) is a more recent initiative. This growing sector has not been included in the analysis as knowledge on the future prevalence of these sites (and the potential for co-location of these areas with other marine uses) remains less developed, but the protection of marine areas for the cultivation of blue carbon is likely to be an area of marine exploitation in the future. [17,18]

- Similarly, applying **alkalinity enhancement** and iron fertilisation processes to enhance the ocean's sequestration capacity is a potential future function of the marine environment (though there are doubts regarding the viability of these approaches). Likewise, the development of **seaweed aquaculture** and the emergence of **blue finance opportunities** could lead to further growth of GVA founded in the use of the UK's marine environment. However, as they are currently more speculative sectors, this economic value is not captured in this analysis.

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[12] European Commission, 2024. *EU Blue Economy report 2024.* Available at: https://oceans-and-fisheries.ec.europa.eu/news/eu-blue-economy-report-2024-innovation-and-sustainability-drive-growth-2024-05-30_en
[13] OECD, 2016. *The Ocean Economy in 2030.* Available at: https://www.oecd.org/sti/futures/Policy-Note-Ocean-Economy.pdf
[14] ibid.
[15] North Sea Transition Authority, 2024. *Carbon capture and storage*. Available at: https://www.nstauthority.co.uk/the-move-to-net-zero/carbon-capture-and-storage/.
[16] Rewilding Britain, 2021. *Blue carbon: ocean-based solutions to fight the climate crisis*. Available at: https://www.rewildingbritain.org.uk/about-us/what-we-say/research-and-reports/blue-carbon.
[17] Hoegh-Guldburg et al., 2019. *The Ocean as a Solution to Climate Change: Five Opportunities for Action*. Available at http://www.oceanpanel.org/climate
[18] The All-Party Parliamentary Group for the Ocean, 2022. *The Ocean: Turning the Tide on Climate Change* Available at: https://static1.squarespace.com/static/62b190dfbf0b9a5e1c75cf07/t/63906b0412462e597883d650/1670408984499/APPG+for+the+Ocean_Turning+the+Tide+on+Climate+Change.pdf

2.2 Literature review and data gathering

To investigate the costs and benefits of seabed mapping to the various in-scope marine sectors, a detailed literature review was undertaken. There was a particular focus on finding literature that presented figures on Gross Value Added[19] as GVA is the best representation of each sector's economic contribution to the economy. The review of secondary research also identified employment data, business growth figures, context on the importance of the sector to the UK economy, and how and why (and to what extent) seabed mapping enables this. This was conducted in relation to the different maritime sectors; Section 5.0 provides further detail on the data identified for each sector.

Various forms of literature were reviewed, including peer-reviewed academic papers, news reports, publications from trade associations, conference papers and technical reports. Much of the quantitative economic data was from the Office for National Statistics (ONS).

Equivalent pre-existing cost benefit studies were also drawn upon, specifically the research undertaken by Deloitte relating to the value of seabed mapping data to the blue economy in Australia[20] and that undertaken by PwC relating to the value for money achieved by the INFOMAR (Integrated Mapping for the Sustainable Development of Ireland's Marine Resource) programme.[21]

The sources were compared against the confidence assessment ratings in Table 1 to ensure only robust literature was reviewed. Where less robust literature was identified (usually due to being older research), cross-referencing was undertaken to ensure that the research is based upon recent and accurate data.

[19] GVA is a measure of the value added by a sector in providing the goods and services it delivers.
[20] Deloitte Access Economics, 2021. *The value of Australian seabed mapping data to the blue economy.* Available at: https://www.deloitte.com/au/en/services/economics/perspectives/value-of-australian-seabed-mapping-data-to-blue-economy.html.
[21] PwC, 2008. *Marine Mapping Study Options Appraisal Report: Final Report.* Available at: https://oar.marine.ie/bitstream/handle/10793/1652/PwC_2008.pdf?sequence=1&isAllowed=y.

Table 1: Overall confidence assessment ratings

Rating	Confidence	Definition	Potential Considerations
0	Unable to quantify	Insufficient detail is available to assess confidence in the data.	• The data will not be used as the basis for decision making.
1	Low	Low confidence in the data. The decision maker must be aware that there are limitations to the use. Further investigation will be required.	• The techniques and methods used may not be the accepted, best practice method. • Incomplete or no metadata. • Lack of clarity as to whether the data is measured, modelled, predicted, or estimated. • Lack of clarity as to when the data was recorded, and over what period. • Dataset may not encompass all activities within the sector. • The data source is over five years old.
2	Moderate	Good quality data but may lack internal quality assurance, full documentation of methods, and have inaccuracies.	• Research methodology published but it is not difficult to determine if this followed "best practice" or was considered "standard" by professionals in that field. • Data is modelled, predicted, or estimated with details of such procedures provided. • Data is measured but precision is low or unclear. • Some date information is provided but may be incomplete. • Some quality control information is published at the point of data collection and/or during data processing. • Data encompasses the majority of activities within the sector. • Data source is within the last two years.
3	High	High quality data, internally quality assessed, high confidence in methodology.	• Detailed research methodology published and using known "best practice" or is considered "standard" by professionals in that field. • Data is measured; precision is high and explicitly stated. • Full date (and updated information where necessary) is provided. • Detailed quality control procedures published at the point of data collection and/or during data processing. • Data encompasses all activities within the sector. • Data source is within the last year.

2.3 Stakeholder engagement

Alongside the literature review, supplementary primary research using qualitative interviews was undertaken. This strengthened understanding of the level of dependency that different marine and maritime sectors exhibit regarding access to mapped seabed data and analysis. It aimed to highlight those activities that are wholly dependent on seabed mapping data and those that are enhanced by it so that a representative attribution factor could be applied to calculating the value that seabed mapping brings to each sector.

To define and quantify this attribution, primary research was undertaken with key stakeholders across identified industries and key stakeholders in the seabed mapping sector. Interviews were focused on sectors for which there were particular data gaps and those with the highest economic contributions to the UK economy. The semi-structured interviews used topic guides to gather in-depth quantitative and qualitative information on their sector's use of seabed mapping and the proportional impact of seabed mapping on enabling relevant operations, investments, and decision-making. Each interview lasted around 30 minutes and the standard topic guide was circulated to interviewees ahead of the interview to inform them of the purpose of the research and allow them to prepare.

In total, 19 interviews were held with representatives from public sector (including some UK CSM members), and private sector organisations undertaking and using seabed mapping. Section A.1.0 shows the breakdown of sectors and organisation types. The interviews were representative of both 'data collectors' and 'data users' to capture the additional value generated by the use of data by organisations which do not undertake their own seabed mapping activities. The names of participating organisations are not provided to ensure confidentiality and data protection.

2.4 Analysis and modelling

The results from the literature review and stakeholder engagement were analysed to provide a forecast of the costs and benefits of seabed mapping in a Cost Benefit Analysis (CBA). The Treasury Green Book[22] defines CBA as 'analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value.' To this end, this research aims to quantify the costs and benefits of undertaking seabed mapping of the whole UK EEZ to modern standards, including for associated non-market values.

2.4.1 The costs of seabed mapping

The costs of seabed mapping include financial costs associated with data collection, derived from turnover figures from companies conducting seabed mapping activities in the UK. These costs encompass direct expenses related to acquiring, processing and analysing seabed mapping data, and ongoing costs relating to data management. Although interviews and a survey were undertaken by UKHO collecting cost data from stakeholders, this data was not considered representative because it was unclear in some instances whether the data provided represented spend in a single year or multi-year costs, the data received was incomplete, and there is a risk of overlap (as multiple stakeholders subcontract seabed mapping activities, there is the potential of double counting by including stakeholder spend and the turnover from seabed mapping companies). Therefore, turnover from companies conducting seabed mapping activities in the UK is used to obtain an indicative annual cost figure in this CBA. It should be noted that using this cost figure is a more conservative estimate in the ratio because the cost of seabed mapping activities are likely to be less than the companies' turnover. An outline of the costs used in the analysis are included in Section 3.0.

[22] HM Treasury, 2022. *The Green Book*. 2022. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020

2.4.2 The benefits of seabed mapping

The UK has a good historical understanding of a limited number of properties of its seabed. However, seabed mapping technologies and capabilities have improved significantly over the past decade and the historical data may not always be relevant for future needs. Also, the seabed can change significantly, sometimes rapidly and sometimes over a longer time period, so historic mapping may no longer be accurate. The benefits calculated in this research are based on the calculated benefits of widespread use of modern standards of seabed mapping.

Each sector was designated an **attribution factor**. It is recognised that calculating the level of 'reliance' on seabed mapping is a particularly challenging concept. Activities in the marine environment are reliant on several aspects. For example, within the shipping industry there are a wide range of items that are essential, not least suitable equipment and trained staff. Thus, it would not be prudent to present a breakdown of essential items and apportion the economic contribution of each, as without one of them, it is likely that the activity would not be able to be completed. Therefore, the attribution of seabed mapping is not 100% for any sector but serves to represent the current and proportionate reliance on seabed mapping. Notwithstanding this, there are sectors where seabed mapping plays a critical role (e.g. in the identification of sites for renewable energy development), and the attribution figure of seabed mapping is higher for these sectors. Where seabed mapping enhances operations but is not essential to their function, the attribution factors reflect this nuanced dependency. The attribution factors for each sector were derived from stakeholder engagement. The attribution factor is applied to the GVA of each sector, so that a suitable proportion of the sector's GVA is considered in the cost benefit ratio.

Where available, a 5-year average was taken for the GVA, to minimise the impact from COVID-19 on the figures and capture any fluctuations in spend between years. Where data was outdated, Gross Domestic Product (GDP) growth rate was used to estimate the GVA of more recent years. Additionally, all costs are presented in real terms, adjusted to 2023 prices. This adjustment accounts for inflation by converting past monetary values into current terms to provide a consistent basis for comparison.

2.4.3 The relationship between costs and benefits

It is important to note that the relationship between investment in seabed mapping data and economic activity is not uniform.

Seabed mapping can sometimes be seen as an investment that facilitates future activity. Thus, the relationship between the investment made and the economic benefits being realised changes through time and varies from activity to activity. For sectors such as offshore energy (both renewable and oil and gas) and telecommunications, seabed mapping is often most utilised prior to the commencement of activities – for instance, when identifying and surveying suitable fields and sites for the development of offshore energy, and suitable locations for laying telecommunications pipelines. When seabed mapping is undertaken, few economic benefits are realised immediately, as the infrastructure is yet to be built. However, as the infrastructure is developed, the expenditure on seabed mapping decreases, as it is more often used for monitoring (e.g. observing sediment and habitat change following the installation of a pipeline or undertaking repairs following natural erosion of concrete subsea foundations). Therefore, the benefit to cost ratio will be highly dependent on whether the infrastructure has been commissioned.

For sectors such as dredging and extraction of marine aggregates, seabed mapping plays an operational role throughout the lifetime of the sector's activities. It is critical to the success of an organisation as it commences its operational activities (e.g. identifying suitable sites for extraction) but continues to be essential to operations as it is used in environmental assessments, site monitoring and operational decision making (e.g. suitable depths for dredging). Therefore the attribution factor of seabed mapping to enabling the sector's growth is consistently high.

For sectors such as shipping and trade, coastal leisure and tourism, and fishing and aquaculture, seabed mapping enhances the sector's growth and operations. These activities occurred before seabed mapping data was available. Mapping therefore does not directly contribute to the sector's activities,

but the use of seabed data greatly assists in the efficiency and safety of these sector's operations (e.g. the identification of suitable fishing sites, the planning for marine leisure activities, or minimising risk in shipping, particularly in more marginal routes such as deep draught in shallow areas).

For sectors such as ports and marine defence, seabed mapping likewise enhances the activities but to a greater extent and is more critical to the optimisation of the sector's activities, and therefore the attribution figure is consistently medium.

2.5 Quality of data

The extrapolation of data points introduces inherent uncertainties, which have been addressed through validating the data points against known benchmarks and historical data. While these steps may mitigate some of the risks, inherent issues associated with the assessment impact the data quality.

2.5.1 Understanding the economic impact of sectors

The sectors included within the analysis have different level of economic impact data available. For some sectors including telecommunications, offshore energy, fishing and aquaculture, robust data was collected from the ONS. However, other sectors are not clearly characterised in ONS data, such as shipping, trade and ports, marine leisure and tourism, marine defence, aggregates and mineral extraction, and environmental conservation and protection. These sectors used industry or government reports to obtain GVA data. Additionally, while some sectors conduct their entire economic activity in the marine environment, others operate in both terrestrial and marine environments. In the analysis, data was extracted only on the marine environment to ensure accuracy.

Another important issue is the potential for double counting. Some activities, such as dredging and port operations, are complementary to one another, which can lead to an overestimation of their economic contribution. To address this, sources of data were used that separated out the GVA of different activities to help prevent against double counting to provide a more accurate representation of each sector's economic impact.

2.5.2 Attribution of economic benefits

The attribution of benefits to seabed mapping has been based on the data collected through stakeholder engagement. It is crucial to acknowledge that survey responses and interviews may contain biases or inaccuracies in terms of under or overestimation. In particular, organisations involved in gathering seabed mapping data are likely to overstate the benefits. For this reason, greater emphasis has been placed on users of seabed mapping data for calculating the benefits.

The attribution figure for each sector is the most challenging component to quantify when calculating the cost benefit analysis. As discussed in Section 2.4.3, the investment in seabed mapping to facilitate the creation of infrastructure often occurs at a different point in time to when the benefits are realised. Moreover, the successful operation of all sectors is dependent on numerous enabling factors, one of which is seabed mapping. The perceived contribution of seabed mapping to the current economic value of each sector is used as the attribution figure.

3.0 Seabed mapping activity and costs

Seabed mapping activity is commissioned by a range of organisations within the UK, including those within the public and private sectors. There are numerous examples of public and private sector partnerships across the seabed mapping sector. The most prolific is the Marine Environmental Data and Information Network (MEDIN) which aims to enable improved decision making due to greater availability

of marine data. Other examples include the Maritime UK Southwest Cluster[23] which brings together regional partners to develop marine centres of expertise (such as offshore renewable energy). The Crown Estate acts as an independent business with oversight of the monarchy's lands and holding, including managing much of the UK's coastlines and seabed, and as such is an important stakeholder in between the public and private sectors. There are also several bi-lateral or tri-lateral organisational partnerships working effectively in this space.

There are numerous public sector bodies in the UK which hold different aspects of oversight for seabed mapping and there are over 30 that use and commission seabed mapping.[24] The UKHO oversees and commissions a number of seabed mapping programmes, provides hydrographic data to maritime organisations across the world and administers the UK Centre for Seabed Mapping (UK CSM), which aims to coordinate the collection, management and access of seabed mapping data in the UK. The Maritime and Coastguard Agency has overall responsibility for the UK's hydrographic obligations under the Safety of Life at Sea Convention (SOLAS) and, supported by the UKHO, systematically surveys the waters around the UK through the Civil Hydrography Programme (CHP). The National Network of Regional Coastal Monitoring Programmes (NNRCMP) collects data in a co-ordinated and systematic manner (in partnership with the MCA and UKHO) to serve the needs of coastal engineering and management. Some entities have their own vessels and equipment for undertaking mapping but most contract to commercial specialist contractors. However, most of the 30+ organisations are data and mapping users, rather than commissioners.

Public sector seabed mapping is usually undertaken as part of multiyear programmes with a defined budget. Examples include the Maritime and Coastguard Agency's annual budget of £5.4 million for undertaking the surveying required to meet the UK's SOLAS obligations, the Defra funded NNRCMP, and the Royal Navy/UKHO Defence Hydrographic Programme. The private sector is increasingly undertaking seabed mapping activities, though the spend and scale of this is less clear than public sector programmes. Private sector seabed mapping is usually undertaken to fill data gaps relating to specific sites, to gather even higher resolution data and to collect data on additional parameters other than those available from publicly available and public sector collected data.

No comprehensive figures for annual spending on UK seabed mapping activities have been published and therefore an accurate and comprehensive figure for UK seabed mapping activities does not exist. This method uses private sector spend on seabed mapping as a proxy. Though this is likely to be a conservative estimate on spend (as it might exclude smaller companies or non-UK companies and excludes expenditure by Port Authorities) it is used in the CBA to remove the risk of double counting expenditure on seabed mapping.

Seabed mapping activities are procured via several routes, including long-term programmes and ad-hoc exercises. However, there are issues including double counting and identifying annualised figures as outlined in Section 2.4.1.

Accordingly, the organisations responsible for the majority of seabed mapping in the UK were identified by attributing their annual turnover as outlined in Table 2. Turnover data has been collated from Companies House and each organisation's annual reports, and a review of their operations (in terms of services offered and markets in which each organisation operates) was undertaken to identify a suitable attribution percentage for spend on seabed mapping undertaken in the UK. As this attribution is an estimate, a range has been provided of lowest to highest turnover attributable to seabed mapping. This attribution also accounted for the fact that some of an organisation's turnover will inevitably relate to non-operational activities, hence the attribution figure is never 100%.

[23] Maritime UK Southwest, n.d. *Maritime UK South West: the leading UK ocean technology cluster*. Available at: https://maritimeuksw.org/
[24] UK CSM, 2022. *Members*. Available at: https://www.admiralty.co.uk/uk-centre-for-seabed-mapping#Members

There are numerous smaller organisations that undertake seabed mapping activities whose turnover is unavailable from publicly available sources; to represent these, an average figure has been calculated (using number of employees as a proxy for organisational turnover). These organisations are: Clinton, Swathe Surveys, XOCEAN, Land Scope, Glanville Geospatial, CMS Geoscience, Aspect, Ultrabeam Hydrographic, SEP Hydrographic, AP Land Surveys, Geosight, A2 Sea, Ocean Ecology, EGS, Sand Geophysics, Titan Surveys and Acteon.

Three public sector organisations also provided a figure for their annual expenditure on seabed mapping. During interviews, two of these organisations stated that their expenditure on seabed mapping is spent on contracting private sector entities to undertake seabed mapping activities. The expenditure of the public sector body which undertakes its own seabed mapping activities (**£550,000** per year) has been included in the CBA as there is no risk of double counting.

The sum of these figures is presented in Table 2 and this figure is used in the calculation of the CBA. Table 2 indicates that a robust estimate of private sector spend on seabed mapping, in addition to known public sector programmes, is **£103.1 million** annually. The level of confidence in the accuracy of this figure is 2 (medium) as it is based on quantitative data and evidence-led evaluation of attribution of operations. This uncertainty is reflected in the range of % attribution – using the lower attribution, the total spend is £72.9 million whilst using the higher estimate of attribution, the total spend is £141.3 million.

Table 2: Private sector seabed mapping costs

Company	Turnover (£m)	% of operations: UK seabed mapping / surveying (low – high range)	Turnover attributed to seabed mapping (£m)	Level of confidence
Gardline	139.0[25]	30[26] (20 – 35%)	41.7	2
Briggs Marine	81.1[27]	20[28] (15 – 25%)	16.2	2
Reach Subsea	149.2[29]	10[30] (5 – 15%)	14.9	2
Fugro	163.0[31]	5[32] (1 – 10%)	8.2	2
OCEAN Infinity Group	14.9[33]	25[34] (15 – 35%)	4.5	2
Andrews Survey	8.2[35]	50[36] (30 – 75%)	4.1	2
Rovco	13.7[37]	5[38] (1 – 10%)	0.7	2
ABPmer	5.5[39]	10[40] (5 – 15%)	0.5	2
Others	*39*	*30 (5 – 75%)*	*11.7*	*1*
		Total	**103.1**	**2**

[25] Gardline Limited, 2022. *Financial Statements.* Available at: https://find-and-update.company-information.service.gov.uk/company/04589821/filing-history/MzM5NDg4MDAyMGFkaXF6a2N4/document?format=pdf&download=0
[26] Gardline, 2024. https://gardline.com/
[27] Briggs Marine Contractors Ltd. 2023. *Annual Report and Financial Statements.* Available at: https://find-and-update.company-information.service.gov.uk/company/SC114978/filing-history/MzQwNTkyMzY4OGFkaXF6a2N4/document?format=pdf&download=1
[28] Briggs Marine, 2024. https://www.briggsmarine.com/marine-services/marine-survey/
[29] Reach Subsea, 2023. *Annual & Sustainability Report.* Available at: https://reachsubsea.no/wp-content/uploads/2024/04/Reach-Subsea-ASA_Annual-and-Sustainability-Report-2023.pdf
[30] Reach Subsea, 2024. https://reachsubsea.no/
[31] Fugro, 2023. *Annual Report.* Available at: https://annualreport.fugro.com/
[32] Fugro, 2024. https://www.fugro.com/
[33] Ocean Infinity Group (UK) Ltd, 2022. *Financial Statements.* Available at: https://find-and-update.company-information.service.gov.uk/company/03072527/filing-history/MzM5NDk4OTM4NWFkaXF6a2N4/document?format=pdf&download=0
[34] Ocean Infinity, 2024. https://oceaninfinity.com/
[35] Andrews Hydrographics Ltd. 2020. *Directors' Report and Financial Statements.* Available at: https://find-and-update.company-information.service.gov.uk/company/01349279/filing-history/MzMxNjA2Njk5NWFkaXF6a2N4/document?format=pdf&download=0
[36] Andrews Survey, 2024. https://www.andrewssurvey.com/
[37] Rovco Limited. 2022. *Annual Report and Financial Statements.* Available at: https://find-and-update.company-information.service.gov.uk/company/09742877/filing-history/MzQwNTI3NTM1MmFkaXF6a2N4/document?format=pdf&download=0
[38] Rovco, 2024. https://www.rovco.com/marine-site-characterisation/hydrographic-survey/
[39] ABP Marine Environmental Research Limited, 2022. *Annual Report and Accounts 2022.* Available at: https://find-and-update.company-information.service.gov.uk/company/01956748/filing-history/MzM5MjQ4NzA2MWFkaXF6a2N4/document?format=pdf&download=0
[40] ABPmer, 2024. https://www.abpmer.co.uk/services/survey-and-monitoring/

4.0 Non-market impacts

The marine environment provides value via the provision of non-market impacts, often relating to environmental protection and maritime safety. Despite no market valuation for these impacts, it is important to consider how seabed mapping contributes to their value. The value attributed to these services and the appropriate attribution factors were calculated using well-substantiated estimates from secondary research (though limitations on available data means that these figures include some evidence-based assumptions).

4.1 Environmental conservation and protection

The marine environment provides numerous vital ecosystem services including coastal protection, water purification and carbon sequestration, in addition to providing the resources and locations for tourism and recreation, a space for enjoyment and a place that benefits wellbeing. It is challenging to place a value on these services, but in 2021 the ecosystem services provided by the UK's marine capital assets were valued at £221 billion.[41,42] In a study by Beaumont et *al*[43], a goods and services approach was taken to estimate the annual value of goods and services provided by marine ecosystems in the UK, which are shown in Table 3.

The goods and services provided by marine ecosystems mentioned in Table 3 are enabled and protected by the use of seabed mapping. Data on the topography of the seabed provides information on what processes take place there or the services that a specific area of seabed may provide (e.g. how the distribution of sediments contributes to coastal protection or disturbance prevention). Mapping the seabed yields information on what areas are suitable for carbon or nutrient storage, which then contributes to gas and climate regulation. In a non-sustainably managed environment, the ecosystem would collapse and cease to provide these services.

It is challenging to calculate an accurate attribution factor to represent the proportion of the value of goods and services provided by ecosystem services that are enabled by seabed mapping. This was devised by considering the extent to which the provision of these services would be affected if modern seabed mapping data was unavailable. Therefore, no value from nutrient cycling, gas and climate regulation and climate regulation and CO_2 sequestration is attributed to seabed mapping in this study. Seabed mapping is utilised in understanding the seabed's structure and properties and how this protects the natural and built environment from environmental disturbance (such as flooding) and therefore a nominal attribution factor is applied for the perceived value of these ecosystems services.

[41] Natural capital is those elements of the natural environment which provide valuable goods and services to people, such as the stock of forests, water, land, minerals and oceans, as defined by Natural Capital Committee, 2017. *Economic valuation and its applications in natural capital management and the Government's 25 Year Environment Plan*. Available at: https://assets.publishing.service.gov.uk/media/6017e8378fa8f53fc01c78d4/ncc-natural-capital-valuation.pdf.

[42] Office for National Statistics. *Marine accounts, natural capital, UK: 2021*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/marineaccountsnaturalcapitaluk/2021

[43] Beaumont, N., Austen, M., Mangi, S. and Townsend, M. 2008. *Economic valuation for the conservation of marine biodiversity*. Available at: https://www.sciencedirect.com/science/article/pii/S0025326X07004535

Table 3: Goods and services enabled by UK marine ecosystems

Goods and services	Description	Monetary value inflated to 2023, per annum (£m)[44]	Attribution to seabed mapping	£m in CBA	Confidence rating
Coastal protection	Natural prevention of infrastructure damage due to flooding.	4,387[45]	5%	219.4	1
Disturbance prevention	Natural structures that provide protection from environmental disturbance.	468[46]	1%	4.68	1
Nutrient cycling	The process of storing, cycling and maintaining nutrients through living marine organisms.	1,248[47]	0%	0	1
Gas and climate regulation	The control of the chemical composition of the atmosphere and oceans by marine organisms.	624[48]	0%	0	1
Climate regulation and CO_2 sequestration	The process of removing CO_2 from the atmosphere and storing it to balance atmospheric conditions.	9.3[49]	0%	0	2
			Total	**224**	

[44] 2024 value calculated using: https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator
[45] Watkiss, P. and Hunt, A. 2012. *Valuing and Monitoring Climate Services.* Available at: https://www.ukclimateresilience.org/wp-content/uploads/2021/01/Final-Report-Met-Office-Valuation-study-Method-and-Case-Studies.pdf.
[46] *Ibid.*
[47] *Ibid.*
[48] Beaumont, N., Austen, M., Mangi, S. and Townsend, M. 2008. *Economic valuation for the conservation of marine biodiversity.* Available at: https://www.sciencedirect.com/science/article/pii/S0025326X07004535
[49] Government Office for Science & Foresight, 2018. *Foresight Future of the Sea.* Available at: https://assets.publishing.service.gov.uk/media/5afab2f440f0b622e060e2b7/foresight-future-of-the-sea-report.pdf

Seabed mapping is used to enhance environmental conservation and protection primarily through the collection of relevant data to inform further research and conservation activities. This occurs both due to regulatory requirements (e.g. JNCC has responsibilities for offshore marine nature conservation set out in the Natural Environment and Rural Communities (NERC) Act 2006[50], the Marine and Coastal Access Act 2009[51] and various other regulations) to support national marine conservation priorities, and by charities and NGOs undertaking vital conservation work.

Many organisations, such as charities, do not have sufficient resources to collect their own seabed mapping data therefore they rely on other organisations who are collecting the data to make it available. One organisation estimated that 90% of its organisational activities are dependent on seabed mapping data which is used to create data products that underpin conservation advice relating to Marine Protected Areas (MPAs) and habitat maps in the UK.[52] These habitat maps are used to monitor change and evaluate the effectiveness of environmental management measures. This also allows regulatory environmental bodies to assess the sensitivity and vulnerability of habitats to environmental pressures or damage (e.g. offshore wind noise or anchoring). The seabed mapping data is also used by charities to inform their conservation efforts. Often, in cases where the charity does not have the funding to pay for the survey themselves, they will use readily available seabed mapping data. During the stakeholder engagement activities, it was highlighted that there is a particular lack of habitat maps from survey data in areas outside of MPAs in the UK.[53] Alongside this there are also quality issues with the inshore data mapping as boats struggle to get close enough to shore to survey these inshore areas, which means many MPAs are also lacking habitat maps.

Access to seabed data enables research activities to inform the planning of conservation areas to be undertaken to allow for targeted protection of marine life, and the prioritisation and planning for the restoration of marine habitats. Other conservation-related activities provided by seabed mapping include monitoring of erosion and seabed landslides, and research into the UK's marine heritage such as ship wrecks. The tracking of marine pollution, particularly from wrecks, was also noted as one of the variety of uses of seabed mapping data where the value is challenging to quantify.

The impacts of climate change will threaten marine environments in many ways, from ocean acidification, rising sea temperatures, invasive species and rising sea levels, all of which will threaten the provision of marine ecosystem services.[54]

According to a 2012 report on case studies of valuing and monitoring climate services, it was estimated that damage as a result of climate change-induced coastal and fluvial flooding could cost the UK £6.6 billion for property and infrastructure.[55] A deep understanding of the seabed is crucial to assist with natural hazard monitoring in the event of extreme conditions like severe wind, storms or tsunamis. Seabed data can be used alongside ocean and tidal data in models that predict the impacts of extreme events like earthquakes or storms on marine environments or coastlines, in order to mitigate the effects of climate change on marine environments. Seabed data can be used to predict the development of sedimentary deposits like sand, clay and silt which form natural floor barriers such as sand dunes. Data on the structure of the seabed is used to predict sediment movement to help with planning protection measures from rising sea levels. The value of protecting this infrastructure is not

[50] UK Government, 2006. *Natural Environment and Rural Communities Act 2006.* Available at: https://www.legislation.gov.uk/ukpga/2006/16/contents.
[51] UK Government, 2009. *Marine and Coastal Access Act 2009*. Available at: https://www.legislation.gov.uk/ukpga/2009/23/contents.
[52] Interview 12
[53] Interview 12
[54] Scottish Wildlife Trust, 2021. *Natural Capital Assessment of the Orkney Marine Region Area.* Available at: https://scottishwildlifetrust.org.uk/wp-content/uploads/2022/02/Orkney-Marine-Natural-Capital-Assessment-Final-Report-compressed-1.pdf.
[55] Paul Watkiss and Alistair Hunt, 2012. *Valuing and Monitoring Climate Services.* Available at: https://www.ukclimateresilience.org/wp-content/uploads/2021/01/Final-Report-Met-Office-Valuation-study-Method-and-Case-Studies.pdf.

included in the CBA ratio as this is 'unlocked' by seabed mapping rather than enabled, but this significant cost avoidance would increase the benefits further.

Seabed mapping is also important in understanding the ocean's role in carbon sequestration. Marine sediments are one of the Earth's most significant carbon stores[56], but the current data used to assess marine carbon stocks is lacking. Seabed mapping data would enable a better understanding of the topography and chemical composition of different areas of the seabed and allow protection against sediment disturbance through activities like drilling, dredging and trawling, which could release the stored carbon into the atmosphere.[57] The All-Party Parliamentary Group (APPG) for the ocean recommend that blue carbon habitat mapping should be undertaken within the UK EEZ to allow for better monitoring, reporting and understanding of the UK's blue carbon stores.[58]

4.2 Compliance with legislation and contingent liabilities

Information provided through the regular completion of seabed mapping is necessary to assist the UK government, both directly and indirectly, in complying with various national and international legislative and regulatory requirements.

Some of these requirements relate to the UK's duty of care to protect the marine environment, such as the Environment Act[59], which requires the UK to undertake activities to protect the marine environment (such as implementing environmental improvement plans to manage water quality). The Act requires the UK to ensure that 70% of the designated features in the MPA network are in a favourable condition by 2042, with the remainder in recovering condition. Many of these activities use seabed mapping data for monitoring progress.

The UK also has obligations under the International Maritime Organization's conventions, including SOLAS (which concerns the safety of ships at sea and requires all ships to carry up-to-date nautical charts, which rely on seabed mapping data to produce), United Nations Convention on the Law of the Sea (which defines the rights and responsibilities of nations in their use of the world's oceans[60]) and International Convention for the Prevention of Pollution from Ships (MARPOL, which aims to eliminate and regulate marine pollution such as oil spills[61]). In order to comply with these conventions and support national conservation priorities, it is crucial that the UK marine environment as well as terrestrial environments are well understood. One stakeholder noted that government agencies undertaking seabed mapping work closely with other North Sea states to collaborate on survey plans, standardise the process, determine risk levels and develop international policy on navigation and maritime safety.

[56] Atwood Trisha B., Witt Andrew, Mayorga Juan, Hammill Edd, Sala Enric, 2020. *Global Patterns in Marine Sediment Carbon Stocks*. Available at: https://www.frontiersin.org/articles/10.3389/fmars.2020.00165/full
[57] The Oxford Scientist, 2022. Could mapping the seafloor help save the planet? Available at: https://oxsci.org/mapping-the-seafloor/
[58] The All-Party Parliamentary Group for the Ocean, 2022. *The Ocean: Turning the Tide on Climate Change* Available at: https://static1.squarespace.com/static/62b190dfbf0b9a5e1c75cf07/t/63906b0412462e597883d650/1670408984499/APPG+for+the+Ocean_Turning+the+Tide+on+Climate+Change.pdf
[59] UK Government, 2021. *Environment Act 2021*. Available at: https://www.legislation.gov.uk/ukpga/2021/30/contents.
[60] United Nations, 1994. *United Nations Convention on the Law of the Sea.* Available at: https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
[61] International Convention for the Prevention of Pollution from Ships, 1978. *International Convention for the Prevention of Pollution from Ships 1973.* Available at: https://assets.publishing.service.gov.uk/media/5a801932ed915d74e622c74f/MEPC_118_52__Annex_II_MARPOL_Amended_14-7-2015.pdf.

Compliance with safety and navigational legislation

A study of the INFOMAR programme[62] estimated that fines for non-compliance would be in the range of €10 million, and that approximately 10% of this avoidance of this cost could be attributed to having a national seabed mapping programme of modern standards mapping of the EEZ. Though this figure has many uncertainties, it represents an estimate of the fines that seabed mapping could assist in avoiding, and therefore this figure of **£1,243,000** (adjusted to £ and 2023 prices) is included in the CBA.

Cost of avoiding oil spills

Accidents that occur in national waters could be attributable to poor charting.[63] The clean-up of such accidents (primarily oil spills) can be costly for the UK. While seabed mapping is used to provide information for marine charting and reduce the frequency of these incidents, it is challenging to accurately monetise the cost of avoided accidents or quantify the extent to which seabed mapping would reduce the probability of these accidents. Previous research has calculated an average mass of oil spilled per year (~16,000 tonnes) and that out-of-date or insufficiently detailed charts would increase this by one-third[64]. To account for the age of the research (conducted in 2010) and the increase in coverage and granularity of seabed mapping since then, the calculations were updated to allow for a 5% increase in spills from a lack of sufficiently detailed or up-to-date seabed mapping. Using the Cost of Averting a Tonne of Oil spilled value of £,1,830[65] (adjusted to 2023 prices to £2,705), this gives an estimated benefit of **£45,444,000** each year through extending and improving the coverage and accuracy of current seabed mapping across the UK EEZ to reduce the likelihood and occurrence of oil spills that occur due to insufficient seabed mapping data.

There are also legislative requirements to be fulfilled relating to seabed mapping as mandated by specific Marine Guidance Notes (MGNs). MGNs give guidance and recommendations about best practice to marine industries on interpretation of law and general safety advice. MGNs cover a range of topics (e.g. keeping safe navigational watch, the appropriate use of signals) and some of these imply the use of seabed mapping to ensure navigational safety. For example, in order to comply with MGN 654[66], developers of any offshore renewable energy installations must adequately assess the impact of their development on marine navigational safety and response risks and mitigate any risks.[67]

Cost of avoiding marine incidents and human fatalities

Seabed mapping data is used for avoidance of maritime incidents. It is difficult to place a monetary value on human life which makes it challenging to attribute the value of seabed mapping to this sector. However, the UK could not provide navigational safety services without some degree of chart information. Interviews with representatives from this sector highlighted that some organisations rely on seabed data for 80-100% of their activities.[68,69]

In 2018, the UK Government's Coastguard Search and Rescue Coordination Network responded to over

[62] PwC, 2008. INFOMAR Marine Mapping Study Options Appraisal Report: Final Report. Available at: https://www.infomar.ie/rd-and-education/publications/infomar-marine-mapping-study-options-appraisal-report
[63] PwC, 2008. *INFOMAR Marine Mapping Study*. Available at: https://maritime-forum.ec.europa.eu/document/download/c4566202-e87f-4c1f-b24b-a697086a12be_en?filename=infomar.pdf&prefLang=it
[64] Anatec Limited (2010). *Financial Benefits of the Civil Hydrography Programme*. Unpublished.
[65] *Ibid.*
[66] Maritime and Coastguard Agency, 2021. *Marine Guidance Note 654. Safety of Navigation: Offshore Renewable Energy Installations – Guidance on UK Navigational Practice, Safety and Emergency Response*. Available at: https://www.gov.uk/government/publications/mgn-654-mf-offshore-renewable-energy-installations-orei-safety-response
[67] Maritime and Coastguard Agency, 2012. Guidance - Offshore renewable energy installations: impact on shipping. Available at: https://www.gov.uk/guidance/offshore-renewable-energy-installations-impact-on-shipping
[68] Interview 1
[69] Interview 2

24,000 incidents in UK waters.[70] Seabed mapping data is crucial for search and rescue operations at sea, and is a vital component to support planning, response and recovery in the event of a maritime emergency. The data allows marine searches to be conducted safely and efficiently. An example of the data used is through the CHP[71] which aims to deliver nautical charting to the relevant organisations for safety at sea purposes.[72]

A study of the financial benefits of the CHP by pwc attempted to devise a suitable value for the avoidance of maritime incidents and resultant fatalities, using the annual cost of averting a fatality to be £1.5m in lost output and human cost (which is increased to £2.22 in 2023 prices).[73] The research indicated that the risk of fatalities from marine accidents has been mitigated in recent years due to improved shipping standards and is low but not negligible, and that out-of-date or insufficiently detailed charts would increase this by one-third.[74] To account for the age of the research (conducted in 2010) and the increase in coverage and granularity of seabed mapping since then, the calculations were updated to allow for a 5% increase (rather than 33%). The number of fatalities per year in different vessels, and the expected additional fatalities that would occur without up-to-date mapping, is presented in Table 4, along with the estimated cost of avoiding these fatalities, which is included in the cost benefit analysis.

Table 4: Estimated costs of avoiding fatalities through improved seabed mapping

Accident	Number fatalities per year	Attribution (on the basis that 5% additional fatalities would occur with out-of-date data)	£ value of prevention – adjusted to 2023 prices
Fishing vessel groundings	0.42 fatalities	0.02	£46,600
Commercial vessel groundings	0.1 fatalities	0.01	£11,100
Recreational craft groundings	0.13 fatalities	0.01	£14,400
		Total	**£72,100**

4.3 Summary of non-market impacts

It is challenging to monetise the cost of avoided accidents, the avoidance of fines for non-compliance, or the value of safety at sea, therefore the estimates presented in Table 5 and utilised in the cost-benefit analysis calculations have low confidence.

[70] UKHO, 2020. *Annual Reports and Accounts 2019/20*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957551/24134_UKHO_AR19_20_Artwork_v29_Accessible_300dpi.pdf.
[71] UKHO, 2014. *The Civil Hydrography Programme*. Available at: https://www.gov.uk/guidance/the-civil-hydrography-programme
[72] Interview 7
[73] Anatec Limited (2010). *Financial Benefits of the Civil Hydrography Programme*. Unpublished.
[74] Anatec Limited (2010). *Financial Benefits of the Civil Hydrography Programme*. Unpublished.

Table 5: Summary of non-market impacts

Non-market impact	£m in CBA	Confidence
Environmental conservation and protection	224.1	1
Cost of avoiding oil spills	45.4	1
Compliance with safety and navigational legislation	1.2	1
Cost of avoiding marine incidents	0.07	1
Total	**£270.8**	**1**

5.0 Market impacts

This section provides in-depth analysis and thematic details relating to the economic value (primarily GVA) and the varying dependencies and uses of seabed mapping for each of the in-scope maritime sectors. These sectors are listed starting with the sector with the highest GVA (adjusted to 2023 prices).

5.1 Shipping, trade and ports

As an island nation, the UK is heavily reliant on shipping and ports for the trading of goods. Around 95% of goods imported to the UK each year arrive by ship, and total trade amounts to almost £1.1 trillion per year.[75] Shipping and ports are also important for other marine sectors, such as offshore energy, defence and tourism, as they support the delivery of essential services and infrastructure required for these sectors. For example, offshore wind farms rely heavily on large vessels for installation, operation and maintenance.[76] The tourism sector also relies on ports for passenger transport, and each year, over 60 million journeys are made by international and domestic visitors passing through UK ports.[77] As the indirect impacts of shipping encompass the vast majority of the UK's trade, sector-specific activities have been limited to the following within this report:

- International and domestic freight transport
- International and domestic passenger transport (cruise and ferry)
- Other shipping activity
- Ports
- Maritime insurance

There is significant overlap between the shipping, trade and ports sectors and other maritime business services, such as shipbroking, ship surveying and maritime consultancy. These ancillary business services have been excluded from the scope of this sector due to the interaction between these services and other marine sectors. Passenger transport has been included in this sector, rather than within coastal tourism, as it is difficult to ascertain the destination of cruise and ferry passengers and so their economic contribution may fit into tourism more broadly, rather than coastal tourism. The economic contribution of the shipping, trade and ports sector to the UK economy is detailed in Table 6.

[75] UK Chamber of Shipping, n.d. *The value of shipping to the UK.* Available at: https://www.ukchamberofshipping.com/policy/the-value-of-uk-shipping

[76] Department for Transport, 2021. *COP26 declaration: Shipping and Offshore Wind – Operation Zero.* Available at: https://www.gov.uk/government/publications/cop26-declaration-shipping-and-offshore-wind-operation-zero/cop26-declaration-shipping-and-offshore-wind-operation-zero

[77] British Ports Association, n.d. *UK Ports Industry.* Available at: https://www.britishports.org.uk/about-us/the-uk-ports-industry/

Table 6: Economic indicators for the UK shipping, trade and ports sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	12,515	CEBR marine sector reports, 2022 (reference year: 2019, adjusted to 2023 prices)	2
Direct employment (FTEs[78])	195,000	CEBR marine sector reports, 2022 (reference year: 2019)	2
Number of businesses	1,360	ONS, UK business: activity, size and location, 2023 (reference year: 2023)	3

The shipping and ports sector is highly dependent on seabed mapping activities, as safe navigation cannot be ensured without a degree of understanding of seabed conditions. As discussed in Section 2.4.3, there are numerous activities that the sector depends on, one of which is seabed mapping; an attribution figure of 25% is therefore used. An interviewee stated that:

> "*Seabed mapping is of utmost importance [to the sector] and should be firmly supported and increased in terms of its accuracy and fidelity…particularly as we move into this evermore intensive use of the marine environment*."[79]

The indirect impacts of seabed mapping in this sector include access to trade through shipping and ports. 95% of the UK's imports and exports, which is approximately equal to £1,659.3 billion, are moved by sea[80,81], though this value is not included in the CBA as it is a value that is 'unlocked' rather than enabled by seabed mapping.

Currently, seabed mapping is used to reduce the risk of grounding and collisions, by monitoring shipping lanes, ports and port approaches. Seabed mapping is carried out more frequently in areas with high sediment build-up, such as the English Channel and southern North Sea, due to the higher margin of error resulting from a more dynamic seabed. [82] As container ships are increasing in size and maritime trade volume is expected to triple by 2050,[83] shipping lanes must also increase to meet this demand. In order to do this, safe navigation of new or wider shipping lanes can be enabled by the expansion of seabed mapping activities into a broader spatial area. This is especially significant, as commercial use of the marine environment from competing sectors will place even greater pressure on navigational safety. Routine resurvey programmes are undertaken by governmental bodies and port authorities to understand depths and clearance for vessels coming in and out of ports.

[78] FTE or full-time equivalent is a unit of measurement of the total amount of full-time employees working at an organisation. It standardizes the hours of full-time, part-time and other types of employees into measurable 'full-time' units.
[79] Interview 17
[80] UK trade in numbers (web version) - GOV.UK (www.gov.uk)
[81] UK Chamber of Shipping (UKCoS), n.d. *The value of shipping to the UK.* Available at: https://www.ukchamberofshipping.com/policy/the-value-of-uk-shipping
[82] Interview 17
[83] UK Parliament Transport Committee, 2023. *Maritime 2050.* Available at: https://publications.parliament.uk/pa/cm5803/cmselect/cmtrans/160/report.html

A joint report published by the UK Marine Investigation Branch (MAIB) and the Danish Maritime Accident Investigation Board (DMAIB) found that insufficient bathymetry data hinders shipping navigation.[84] Where data errors occur, or data is unavailable, there is a greater reliance on human ability to navigate and ensure safe passage, which can lead to a higher incidence of accidents. The report also highlights the importance of balancing high-definition bathymetry against the drawbacks of 'enormous data sets'.[85] Reduced risk through improved seabed mapping data would also benefit the marine insurance sector, as maritime incidents, such as anchoring on telecommunications cables, are becoming increasingly common.[86] A recent report by the Environmental Audit Committee on the future of the UK shipping sector with regards to net zero and decarbonisation[87] recommended that the UK Government's revised Clean Maritime Plan must contain "at a minimum" four measures, one of which is the implementation of "measures to leverage the UK's expertise in shipping law and hydrography so as to support route optimisation measures in global shipping". It further recommended that this route optimisation should be achieved through the utilisation of UKHO's global charting resources. This supports how ongoing seabed mapping to a high quality has a critical role in decarbonising shipping and contributing to the UK's net zero future.

5.2 Offshore energy

The UK offshore energy sector comprises oil and gas exploration and extraction, as well as renewable energy generation such as offshore wind. The UK Government has committed to achieving net zero by 2050,[88] and offshore and coastal renewable energy is expected to play a significant role in ensuring the transition to a green economy. These include offshore wind, wave, tidal stream and tidal range. The largest offshore renewables capacity is in offshore wind, which provides 13.9 gigawatts (GW) of energy per year. The UK Government has set ambitions to grow installed capacity to 50GW by 2030.[89] However, oil and gas currently accounts for around 74% of the UK's energy needs, and domestic production of oil and gas met 57% and 47% of UK demand respectively in 2023.[90] Despite the ambitious net zero target, in 2023, the UK Government mandated new licencing opportunities for oil and gas exploration in the North Sea, although this may be revoked with the change in Government in 2024.[91] By supporting the domestic oil and gas industry in the future, the Government seeks to protect British jobs and decrease dependence on imports from hostile countries, such as Russia.[92] This will bolster energy security until more progress is made on renewables and nuclear.

The UK offshore oil and gas industry comprises exploration and extraction activities. Exploration processes include the research and discovery of potential sites for oil and gas which then enables companies to confidently begin drilling and extracting oil and gas. In the UK, the North Sea Transition Authority (NSTA) regulates the licensing of oil and gas projects, which are predominantly concentrated in the North Sea as well as partially in the Irish Sea.[93] The economic contribution of the domestic oil and gas sector to the UK economy is detailed in Table 7, whilst the economic contribution of the domestic offshore and coastal renewable sector to the UK economy is detailed in Table 8 (overleaf).

Table 7: Economic indicators for the UK oil and gas sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	10,140	ONS GDP output approach – low-level aggregates (reference year: 2023)	3
Direct employment (FTEs)	27,600	UK Extractive Industries Transparency Initiative, 2022[94]	3
Number of businesses	300	ONS UK business: activity, size and location (reference year: 2023)	3

Table 8: Economic indicators for the UK offshore and coastal renewable energy sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	1,778	ONS, Environmental Goods and Services sector (EGSS) estimates; ONS, Low Carbon and Renewable Energy Economy (LCREE) Survey estimates, UK (reference year: 2020) (adjusted to 2023 prices)	2
Direct employment (FTEs)	12,400	ONS Low Carbon and Renewable Energy Economy (LCREE) Survey estimates, UK, 2014 to 2022 (reference year: 2022)	3
Number of businesses	3,000	ONS Low Carbon and Renewable Energy Economy (LCREE) Survey estimates, UK, 2014 to 2022 (reference year: 2022)	3

Oil and gas exploration is highly dependent on seabed mapping. Accounting for the numerous activities that enable the operations of the sector, seabed mapping dependency is assumed to be 30%, based on research into operational activities and an interview with an oil and gas company, where it was stated that seabed mapping data:

> *"Is of massive value…mainly on de-risking."*[95]

Seabed mapping surveys, primarily marine seismic surveys, are used to locate and understand the properties of potential oil and gas sites.[96] More detailed surveys, including multibeam, side-scan sonar and shallow seismic exploration, are then conducted during the planning stage of extraction to reduce the risk of geohazards. For example, a shallow seismic exploration survey is used to test for shallow gas when drilling new wells.[97] This data is also used to create an environmental baseline for the site and reduce risk to the marine environment. Data is then shared with regulators to ensure that projects meet

[84] MAIB & DMAIB, 2021. *Application and usability of ECDIS.* Available at: https://dmaib.com/media/8502/ecdis_application_and_usability.pdf
[85] MAIB & DMAIB, 2021. *Application and usability of ECDIS.* Available at: https://dmaib.com/media/8502/ecdis_application_and_usability.pdf
[86] Interview 17
[87] House of Commons Environmental Audit Committee, 2024. *Net zero and UK shipping.* Available at: https://committees.parliament.uk/committee/62/environmental-audit-committee/news/201771/committee-publishes-report-on-net-zero-and-the-uks-maritime-sector/
[88] BEIS, 2021. *Net Zero Strategy: Build Back Greener*. Available at: https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf
[89] Department for Business & Trade, n.d. *Offshore wind.* Available at: https://www.great.gov.uk/international/content/investment/sectors/offshore-wind/#:~:text=The%20UK%20currently%20has%2013.9,in%20future%20seabed%20leasing%20auctions.
[90] BBC, 2024. *Offshore Energies UK report: Oil and gas fight for survival.* Available at: https://www.bbc.co.uk/news/uk-scotland-scotland-business-68668648
[91] UK Government Prime Minister's Office, 2023. *New opportunities for North Sea oil and gas.* Available at: https://www.gov.uk/government/news/new-opportunities-for-north-sea-oil-and-gas
[92] Ibid.
[93] North Sea Transition Authority (NSTA), 2024. *UKCS Oil & Gas Activity*. Available at: https://datanstauthority.blob.core.windows.net/external/ukcs_maps/UKCS_Oil_and_Gas_Activity.pdf
[94] UK EITI, 2023. *Oil and Gas in the UK*. Available at: https://www.ukeiti.org/oil-gas
[95] Interview 14
[96] Shell, n.d. *Marine seismic surveys.* Available at: https://www.shell.com/what-we-do/oil-and-natural-gas/exploration/marine-seismic-surveys.html
[97] Interview 14

the requirements of licences and permits for oil and gas extraction in the area.

The offshore and coastal renewable energy sector is *data enabled* by seabed mapping, as it uses the full range of seabed data, from the design stage to the operation and decommissioning stages.[98] Seabed mapping dependency for this sector is assumed to be 30%, based on interviews with offshore and coastal renewables organisations.[99] The primary reasons for conducting surveys are to select sites and assist the design and engineering processes. For example, the seabed is mapped at the site from the pre-construction phase and then monitored throughout the project's lifetime. This ensures that risks such as cable depths and foundation scouring can be assessed continuously.[100] The early stages of offshore renewable developments use publicly available data. However, the requirement for higher-resolution data increases throughout the life cycle of a project. Developers contract private charter vessels and personnel to conduct the more detailed surveys. The data from these surveys are supplied to UKHO in line with MCA consent requirements, however, the data are not generally shared for purposes beyond the project due to commercial sensitivities. This leads to the duplication of data and increases seabed mapping costs, particularly in the private sector where commercial interests reduce incentives for collaboration.

Currently, there is significant pressure from competing commercial interests on seabed resource in the UK, which has an indirect impact on the renewables sector. The Crown Estate is in the process of mapping out the uses of the seabed by modelling the resource requirements of various sectors, including renewables, to enable the delivery of net zero and nature recovery. The Government's publicly owned energy company, Great British Energy, has announced a partnership with The Crown Estate with the aim of accelerating investment in renewable energy projects in the UK, particularly for the provision of locations for wind farms.[101] The Crown Estate has also recently begun carrying out its own surveys, where publicly available data is lacking, to accelerate the deployment of offshore wind.[102] Seabed data can increase the efficiency of the consenting process.[103] The speed of the consenting process is particularly significant in the context of an increasingly busy marine environment, where activities such as shipping and navigation are in competition with renewables. Stakeholders stated that a number of renewable projects have also not progressed in the past because seabed conditions have not been as expected.[104] The availability of better-quality public data has the potential to enable a more holistic approach across the various sectors competing for seabed space, accelerate the consenting process and attract more investment to the sector by reducing risk. A more efficient approach to offshore renewable planning, which fosters collaboration between seabed mapping data users, would benefit the UK Government in meeting its 2050 net zero target.

5.3 Coastal leisure and tourism

Coastal leisure and tourism comprise all recreation activities, set in or reliant on the coastal environment. These include visiting the beach, cycling, hiking, sailing, powerboating amongst others. Coastal leisure and tourism activities are mostly concentrated in the South West and South East of the UK, which represent 38.4% and 29.7% respectively of turnover directly contributed by the leisure marine industry.[105] Coastal leisure and tourism has not yet recovered to pre-COVID-19 levels, however, the pandemic saw a

[98] Interviews 6 & 15
[99] Interviews 6 & 15
[100] Interview 15
[101] BBC News, 2024. *UK secures seabed land deal to boost windfarms.* Available at: https://www.bbc.co.uk/news/articles/crglp32zzw2o
[102] The Crown Estate, 2023. *The Crown Estate to digitally map scenarios to inform co-ordinated approach to future seabed use*. Available at: https://www.thecrownestate.co.uk/news/the-crown-estate-to-digitally-map-scenarios-to-inform-co-ordinated-approach
[103] Interview 6
[104] Interview 6
[105] Centre for Economics and Business Research, 2022. *The economic contribution of the UK Leisure Marine industry*. Available at: https://www.maritimeuk.org/media-centre/publications/2022-cebr-reports/

boom in accessible recreation activities, such as stand-up paddleboarding and kayaking,[106] whilst domestic holidays also increased. As of 2024, this trend towards domestic holidays has seen a slight reversal, whilst domestic visitors are also booking later, spending less and shortening the length of their holidays.[107] The economic contribution of the coastal leisure and tourism sector to the UK economy is detailed in Table 9.[108]

Table 9: Economic indicators for the UK coastal leisure and tourism sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	7,197	European Commission, 2020; CEBR, 2019 (reference year: 2018, adjusted to 2023 prices)	2
Direct employment (FTEs)	280,035	European Commission, 2020; CEBR, 2019 (reference year: 2018)	2

The coastal leisure and tourism sector in the UK has a relatively limited dependency on seabed mapping. The attribution figure was modelled at 5% based on the relative importance of seabed mapping in determining suitability and safety of marine leisure and tourism activities; most marine coastal leisure and tourism activities are not directly impacted by seabed mapping. The activity with the highest dependency is passenger transport by cruise and ferry, however, this has been included within the scope of shipping in this report. Recreational boating is the next most reliant activity on seabed mapping. Recreational sail boats and powerboats which are docked or launched from ports and harbours depend on seabed mapping for access to the sea. Inshore and offshore recreational boating is also impacted by seabed mapping activities due to risks associated with navigational safety. Other enhanced sectors include scuba diving and exploring wrecks and reefs. The GVA of marine recreation in the UK in 2022/23 was £1.67bn.[109]

5.4 Marine defence

The defence sector uses high resolution seabed mapping data to support national security through delivering strategic commitments and producing navigational charts for the Royal Navy. The Royal Navy's remit covers the UK and overseas territories.[110] This data is used to ensure safe routes in and out of strategic ports to facilitate the transfer of oil, gas and trade and to enable the swift reopening of ports if their use was compromised (through e.g. a hostile attack or natural disaster). This data is also used to monitor and protect the UK's national critical infrastructure (primarily cables and pipelines). This data can also enhance situational awareness for submersible and surface vessels, and amphibious vehicles and air platforms. This enhanced understanding of the marine environment can be used to support emergency,

[106] The Economist, 2024. *Why so many Britons have taken to stand-up paddleboarding.* Available at: https://www.economist.com/britain/2024/04/26/why-so-many-britons-have-taken-to-stand-up-paddleboarding
[107] ITV News, 2023. *Staycations face 'significant changes' as the costs crisis creates new holiday trends*. Available at: https://www.itv.com/news/2023-08-02/the-costs-crisis-is-creating-new-holiday-trends
[108] It is important to note that the figures are mostly derived from reporting by the European Commission and due to the UK's exit from the European Union in 2020, the last reported figure is from 2018.
[109] British Marine, 2024. *British marine unveils comprehensive report on the economic impact of the UK leisure, superyacht & small commercial marine industry for 2022-23.* Available at: https://www.britishmarine.co.uk/news/2024/April/british-marine-unveils-comprehensive-report-economic-impact-uk-leisure-superyacht-and-small-commercial-marine-industry-2022-23
[110] Ministry of Defence, n.d., *Overseas Territories.* Available at: https://assets.publishing.service.gov.uk/media/5a790a78ed915d07d35b4643/overseas_territories.pdf

military and humanitarian endeavours.[111] Economic indicators for the defence sector are not widely available (likely due to the confidentiality and sensitivity required by the sector), but this section presents economic indicators relating to maritime defence operators calculated using relevant SIC codes and applying a "defence weighting" generated using ONS PRODCOM data.[112,113,114]

Table 10: Economic indicators for the UK defence sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	2,178	JEDHub Annual Economic Report: Accompanying Data Tables, Weighted GVA (reference year: 2021, adjusted to 2023 prices)	2
Direct employment (FTEs)	24,566	JEDHub Annual Economic Report: Accompanying Data Tables, Weighted Employment (reference year: 2020)	2

The maritime defence sector is highly reliant on seabed mapping data. Accounting for the numerous activities that enable the sector to operate effectively, an attribution figure of 25% was used.

Uses of the data include identifying safe routes in and out of harbours, protecting the locations of miles of telecommunications cables (which are vital for internet access, supporting financial transactions and the sharing of essential data) and seabed gas and oil pipelines, as well as cables that provide energy to the UK. These can be vulnerable to attack as adversaries may wish to threaten critical subsea national infrastructure.[115] Surveillance vessels are used to protect this infrastructure, which require high quality seabed mapping data. This also raises the importance of data confidentiality, as adversaries could use this data to target critical infrastructure. One stakeholder suggested that with the increased use of untethered autonomous vehicles, the precision of this knowledge is becoming more important.[116] Stakeholder engagement highlighted the critical importance of the UK being able to defend these seabed assets:

> *"You will cause far more havoc to society by cutting a couple of cables or pipelines than you will ever achieve from dropping a bomb on somewhere… So you can imagine very quickly, they've now not just impacted a small group in a particular*

[111] Maritime Foundation, 2022. *Seabed mapping: a critical component of infrastructure*. Available at: https://www.maritimefoundation.uk/publications/maritime-2023/seabed-mapping-a-critical-component-of-infrastructure/
[112] JEDHub, 2023. *JEDHub Annual Economic Report: Accompanying Data Tables*. Available at: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fjedhub.org%2Fdocs%2F2023%2F20230504_JEDHub_AER_Data_Tables_v1.0.xlsx&wdOrigin=BROWSELINK
[113] ONS, 2023, *UK manufacturers sales by product*. Available at: https://www.ons.gov.uk/businessindustryandtrade/manufacturingandproductionindustry/datasets/ ukmanufacturerssalesbyproductprodcom
[114] The GVA of the defence sector was derived from the JedHub 2023 report. In the report, SIC (Standard Industrial Classification) codes were used to find GVA for relevant sectors from the ONS GDP output approach dataset, specifically for the following SIC codes: 30.1: Ships and boats, 25.4: Weapons and Ammunition, 30.3: Air and Space. GVA values for codes 25.4 and 30.3 were excluded in this report as considered irrelevant to maritime defence. A "defence weighting" was calculated based on the production value of defence related SIC codes within SIC code 30.1. An ONS PRODCOM dataset provided production values for a more detailed set of SIC codes and enabled selection of defence related SIC codes. The weighting calculation involved comparing these selected values to the total production value for the Ships and Boats SIC code (30.1). This was then applied to the GVA value from ONS to ensure it reflected the defence-related aspects.
[115] UK Parliament, 2023. *Seabed warfare: Protecting the UK's undersea infrastructure.* Available at: https://commonslibrary.parliament.uk/seabed-warfare-protecting-the-uks-undersea-infrastructure/
[116] Interview 3.

location, they've now impacted 40% of 70 million[people] ."[117]

To note, the value of defending ports and wired telecommunications are covered in their respective sections as opposed to this section on marine defence.

5.5 Wired telecommunications

The wired subsea telecommunications industry is highly dependent on seabed mapping data hence an attribution figure of 30% is used.

Wired telecommunication directly relies on seabed mapping data as it utilises submarine communication cables, which are laid on or below the ocean floor between land-based stations to carry telecommunication signals between continents. These cables also indirectly support data transmission through wireless, satellite and other telecommunications systems. These cables are the backbone of the global internet; this critical infrastructure is utilised for 95% of global financial interactions and they are estimated to carry 95% of all international digital data, meaning damage to these cables would cause significant disruption to huge proportions of the national (and global) population. [118,119]

Table 11: Economic indicators for the UK wired telecommunications sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	1,970	ONS - non-financial business economy (reference year: 2021, adjusted to 2023 prices)	1
Total employment costs (£m)	699	ONS, non-financial business economy (reference year: 2022)	2
Number of businesses	1,703	ONS, non-financial business economy (reference year: 2022)	2
Total turnover (£m)	2,123	ONS, non-financial business economy (reference year: 2022)	2

The rest of this section outlines information provided by stakeholders during interviews. Stakeholders indicated that subsea cables require an initial survey to collect bathymetry data before installation.[120] These are commissioned by subsea cabling contractors, who collect data on a project-by-project basis. The initial desk study is done using existing data, so contractors are entirely reliant on good quality seabed mapping data.[121] Following this, specific data is collected along the cable route to reduce risk by identifying seabed obstructions such as unexploded ordnances and to protect the environment.[122] Any level of enhanced seabed mapping data would reduce survey costs, particularly boat charter costs, which can cost tens of thousands of pounds per day.[123]

[117] Interview 3.
[118] IISS, 2024. *France's Deep Dive into seabed warfare*. Available at: https://www.iiss.org/online-analysis/military-balance/2022/02/frances-deep-dive-into-seabed-warfare/
[119] Interview 3.
[120] Interview 5.
[121] Interview 10.
[122] Interview 10.
[123] Interview 10.

Unlike power cables, subsea telecommunications cables do not require regular monitoring and maintenance. However, damages to telecommunications cables are disruptive and can be costly. One stakeholder stated that repairs to telecommunications cables are less costly than repairs to power cables (£10m+), but are still expensive, with repairs in risky areas costing from £500,000 to over £1m.[124]

Another stakeholder highlighted the importance of precision of knowledge with untethered autonomous vessels, as they rely on high quality seabed mapping data to function.[125] In ever-changing marine environments, up-to-date data is especially important as autonomous vessels may lack the awareness and responsiveness of a human operator.

Numerous stakeholders highlighted the vulnerabilities resulting from growing reliance by states on seabed infrastructure and notably undersea cables that are estimated to carry 95% of all international digital data.[126,127] Ongoing seabed mapping is required to reduce the risk of damage (intentional and otherwise) to these cables, increase the security of information and financial systems and reduce installation and repair costs of new and existing wired telecommunications infrastructure.

5.6 Fishing and aquaculture

Fishing and aquaculture make a significant economic and cultural contribution to the UK. Demand for fish in the UK and abroad is growing, and the proportional value of fisheries and aquaculture in the UK is roughly split 50/50. The economic contribution of the fishing and aquaculture sector to the UK economy is detailed in Table 12.

Table 12: Economic indicators for the UK fishing and aquaculture sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m)	568	ONS, GDP output approach – low level aggregates, 2024 (reference year: 2023)	3
Direct employment (FTEs)	12,500	ONS, Business Register and Employment Survey (BRES), 2023 (reference year: 2022)	3
Number of businesses	4,070	Nomis, UK Business Counts, 2024 (reference year: 2023)	3

It is modelled that 15% of the activities of the fishing and aquaculture sector are dependent on seabed mapping data. This is because not all fishing organisations (particularly smaller operators) use seabed mapping extensively, but when used, its primary use is to increase efficiency in fishing (thereby reducing time at sea and fuel consumption), reduce accidents, locate reefs, and reduce damage to the marine environment from anchors.[128] Fisheries may also use habitat mapping to locate and quantify fish populations in order to efficiently manage fishing efforts.[129] Hence this sector is **data enhanced** by

[124] Interview 10.
[125] Interview 3.
[126] IISS, 2024. *France's Deep Dive into seabed warfare*. Available at: https://www.iiss.org/online-analysis/military-balance/2022/02/frances-deep-dive-into-seabed-warfare/
[127] Interview 3.
[128] Todd, B and Shaw, J. 2009. *Applications of Seafloor Mapping on the Canadian Atlantic Continental Shelf*. Available at: https://www.erudit.org/en/journals/geocan/2009-v36-n2-geocan36_2/geocan36_2ser06.pdf
[129] Agri-Food & Biosciences Institute, n.d. *Seabed Mapping Project*. Available at: https://www.afbini.gov.uk/articles/seabed-mapping-project#:~:text=the%20RV%20Corystes-,Habitat%20mapping%20and%20fisheries,develop%20more%20effectively%20management%20regimes.

seabed mapping. As the use of the seabed is becoming more intense and there is more seabed infrastructure, seabed mapping data will become more important to the sector to reduce the likelihood of accidents in the fishing industry.

5.7 Marine aggregates and minerals extraction

The UK has significant resources of marine aggregates. The extraction of marine aggregates (primarily high-quality sand and gravel) and minerals is an important contributor to the UK's construction industry. Uses of these materials are primarily as a source of aggregate for making concrete to be used in housebuilding and major infrastructure projects. In 2022, an estimated 20 million tonnes of sand and gravel were dredged from the UK's seabed, and this figure has remained fairly constant over the last five years.[130,131] The economic indicators include data from two sources from BMAPA (British Marine Aggregate Producers Association). BMAPA only covers England and Wales, although this data can be used to represent the UK, as there are currently no areas licenced for marine aggregate extraction in Scotland or Northern Ireland.[132,133]

Table 13: Economic indicators for the UK aggregates and minerals extraction sector

Economic indicator	Quantity	Source(s)	Confidence rating
GVA (£m) - projected	404	Projection calculated using: Stebbings et al., The marine economy of the United Kingdom (reference year: 2014) BMAPA, Area Dredged (reference year: 2022) Bank of England, Inflation Calculator (reference year: 2022)	2
Direct employment (FTEs)	337	BMAPA, Sustainable Development 2020/2021 (reference year: 2020)	2

The availability of detailed seabed mapping is critical for continuing the efficient and sustainable extraction of aggregates and minerals from the seabed; hence the modelled attribution figure is 50%.

[130] British Geological Survey, 2007. *The strategic importance of the marine aggregate industry to the UK*. Available at: https://www.bmapa.org/documents/BMAPA_download.pdf
[131] Marine Product Association, 2022. *Marine Aggregate Extraction – 25th Annual Report*, Available at: https://bmapa.org/documents/25th-Area-of-Seabed-Dredged-Report-2023.pdf
[132] Marine Scotland Assessment, *Aggregates*, Available at: https://marine.gov.scot/sma/assessment/aggregates
[133] The Crown Estate, *Marine Aggregates – Annual Review 2022*. Available at: https://www.thecrownestate.co.uk/media/4243/marine-aggregates-annual-review-2022.pdf

As with other sectors, stakeholders in the aggregates sector use a combination of public domain data and their own collected data to determine suitable locations for the extraction of aggregates and minerals. In addition, stakeholders need to understand the cumulative effect of the interaction of licence areas, making the surveying increasingly more complex. Data is provided to regulators and surveying is driven by regulatory requirements. One stakeholder stated that public domain data at a resolution of 1km^2 is sourced from the British Geological Society (BGS), although this is used to augment the development of high-resolution data (100m^2 or higher) which is required for aggregate and mineral extraction.[134]

> *"[Seabed mapping] is absolutely our core business. if you haven't got the data, you haven't got resources to dredge… you can't satisfy your regulatory permissions and EIAs to support licence decisions… [it is] central to the viability of the business."*[135]

To increase the efficiency of data collection and reduce duplication of effort and work at a sectoral level to acquire data, the sector has taken a coordinated approach to data collection. From the interviews it is understood that sites of interest are grouped into discrete regional associations and operators coordinate initiatives and commission surveys to collect generic data to support multiple operators. Following this, individual operators conduct more ad-hoc data collection as required. New compliance requirements were introduced in 2012 and the industry joined together to develop a staggered five-year cycle, driven by the need for consistency and cost efficiency.[136]

One stakeholder suggested that activities in this sector are data- and evidence-led. The onus is on the developer to ascertain a site's suitability and monitor impacts. Shallow seismic and multi-beam data have enabled better decision making and the expectations of operators are higher. This kind of data enables more responsible operations as there is a good evidence base on direct and indirect impacts as a result of more focused data collection and monitoring.[137] The biggest uncertainty they face is placing their activities into context as there are several aspects to consider when choosing sites (such as proximity to suitable onshore infrastructure[138]). Better data (and therefore a better understanding of potential sites) would result in more intelligent decision making when choosing sites for extractions, limiting impacts, and increasing efficiency in site identification.[139]

5.8 Dredging

Dredging involves moving material from one area of the seabed to another, including the removal of material from the seabed. There are several types of dredging including navigational dredging (deepening of berths and channels for navigation), clearance dredging (removal of accumulated material not associated with navigation) and aggregate dredging (extraction of material for construction.[140] Aggregate dredging falls under marine aggregates and is covered in Section 5.7.

Dredging usually falls into one of two categories: capital dredging and maintenance dredging. Capital dredging involves deep removal of material that has not previously been dredged, whereas maintenance dredging involves the removal of recently accumulated material (e.g. sand) from navigation channels and other areas where vessels require a guaranteed minimum depth.[141]

Table 14: Economic indicators for the UK dredging sector

Economic indicator	Quantity	Source	Confidence rating
GVA (£m) – projected	177	Oxford Economics, 2011 (adjusted to 2023 prices)[142]	1
Employment	547	Oxford Economics, 2011[143]	1

The latest estimate for the GVA of the dredging industry is from 2008, with a value of £114m. Little recent data is available on the economic indicators of the dredging industry, therefore a GVA projection was calculated from the most recent estimation. It is important to note that the dredging sector, which primarily supports shipping and ports, is dependent on the health of the overall economy, given the UK's dependence on imports. Therefore, it is expected that the growth rates for the sector are set as the same for the expected growth of the UK economy. Thus, GDP yearly growth rates from ONS were used to calculate projected estimates for 2023.[144] It is also important to note that dredging undertaken by Port Authorities is assumed to be included within the GVA of ports (see Section 5.1), in line with the methodology provided by the Inter-Agency Committee on Marine Science and Technology at Southampton Oceanography Centre.[145]

When asked how reliant dredging organisations were on seabed mapping, one stakeholder stated:

> *"That's fairly easy, it's 100%. If we don't do the surveys, we don't know what material to take away, we don't know the start point, we don't know the end point."*[146]

To acknowledge that this is anecdotal evidence, the dependency of the dredging sector on seabed mapping has been set at 50% (with an uncertainty range of 60 – 100%). If the data is not available, then companies do not know where dredging is required and to what depth. Multibeam surveys are used to collect bathymetry data before dredging can take place.[147] Seabed mapping is also critical in terms of habitat surveys and undertaking environmental impact assessments for compliance with the site licensing process. Stakeholder engagement also indicated that surveys are also used to monitor the rate of infill, as this can vary with weather patterns. This is important in determining the frequency of required dredges. For example, in South Wales, surveys are conducted at ports every 4-6 weeks.[148]

[134] Interview 9
[135] Interview 9
[136] Interview 9
[137] Interview 9
[138] Interview 6
[139] Interview 9
[140] Marine Management Organisation, 2019. *Guidance: Dredging*. Available at: https://www.gov.uk/guidance/dredging
[141] Ibid.
[142] Oxford Economics, 2011. *The economic impact of the UK maritime services sector: ports.* Available at: https://busnes.senedd.cymru/documents/s25437/EBC4-09-14%20p.2%20-%20Atodiad.pdf
[143] Ibid.
[144] ONS, 2024. *Gross Domestic Product: Year on Year growth: CVM SA %.* Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/ihyp/pn2
[145] The Inter-Agency Committee on Marine Science and Technology Southampton Oceanography Centre, 2002. A new analysis of marine-related activities in the UK economy with supporting science and technology. Available at: https://medin.org.uk/sites/medin/files/documents/marine_related_activities.pdf
[146] Interview 16
[147] Interview 16
[148] Interview 16

5.9 Summary of market impacts

Table 15 provides a summary of the economic value for each marine sector, and its relationship with seabed mapping. The total figure for market impacts attributable to seabed mapping is £8,629 million. When the lower attribution is used, the total figure is £4,530 million; when the higher end of the attribution range is used, the total figure for attributable benefits is £12,728 million.

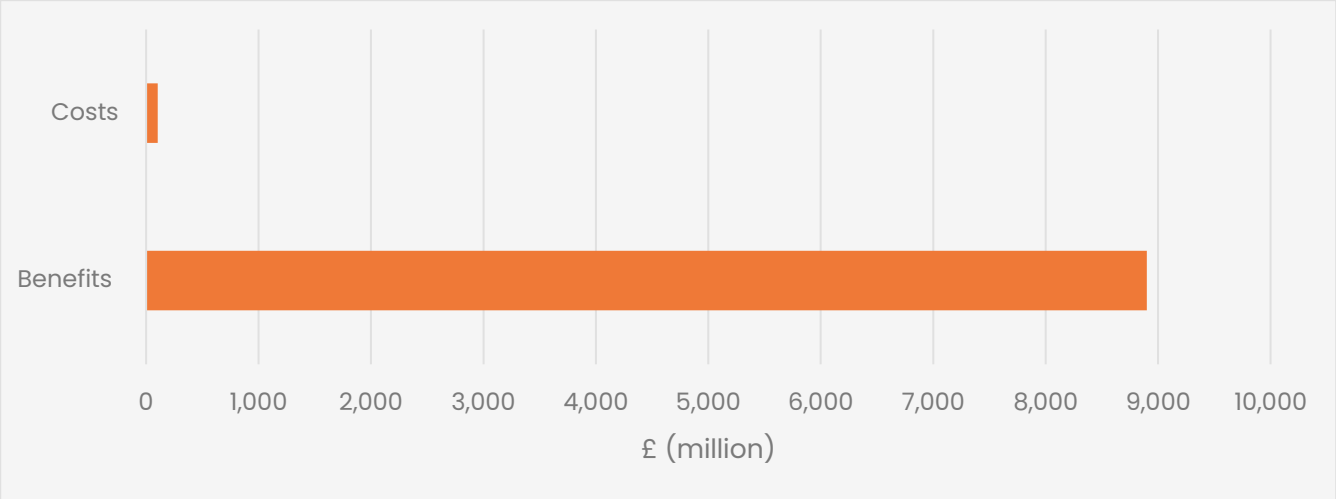
Table 15: Summary of the market impacts of seabed mapping

Economic sector	Economic value (2023 prices, £m)	% attribution to seabed mapping (low to high range)	Attributed economic value (2023 prices, £m)	Confidence
Shipping, trade and ports	12,515	25% (10-40%)	3,129	2
Offshore energy	11,918	30% (20-40%)	3,576	2
Marine defence	2,178	25% (10-40%)	545	2
Telecommunications	1,970	30% (20-40%)	591	2
Aggregates and mineral extraction	439	50 (25-75%)	219	2
Coastal leisure and tourism	7,197	5 (1-10%)	396	2
Fishing and aquaculture	568	15 (10-20%)	85	2
Dredging	177	50 (25-75%)	89	2
		Total	**8,629**	

6.0 Cost benefit analysis results

The cost benefit analysis reveals that seabed mapping in the UK presents significant benefits that far outweigh the associated costs. The analysis includes the identified costs and benefits from the literature review and stakeholder engagement interviews and surveys. The results from the cost benefit analysis are presented in Figure 1.

Figure 1: Cost Benefit Analysis Results



The benefits included in the cost benefit analysis came from attribution of sectoral GVA to seabed mapping. The costs were calculated based on turnover data from private sector seabed mapping companies and turnover was used as a proxy to estimate the costs associated with seabed mapping (using an evidence-led evaluation of each company to determine the proportion of turnover attributable to seabed mapping in the UK). Turnover data was unavailable for many of the smaller companies which contribute to seabed mapping in the UK so an average figure was used to represent their contribution.

Based on 2023 data, the estimated benefits amounted to approximately £8.9 billion, while the estimated costs were about £103 million. This results in a **cost benefit ratio of £86 in benefits for every £1 spent on seabed mapping**. Though the value for money of a project or programme, and the decision whether to invest in it, will be determined by many factors, an example framework for establishing the relative significance of a CBA is that any CBA ratio that is greater than 1:4 (£4 gained for every £1 invested) is deemed 'Very High'.[149]

It should be noted that this report presents one CBA as an average ratio for all seabed mapping activities across the UK EEZ. The manifestation of this ratio will be geographically and temporally variable. A seabed survey in an area with potential to become an offshore wind farm will yield higher benefit than in a remote area with few exploitable resources as there is a spatial dimension to the benefits and costs, and one of the greatest strengths of seabed mapping is to unlock economic benefits of new and/or unknown locations. The approach to seabed mapping in the UK is increasingly focused on realising specific benefits in a single site (e.g. development of a wind farm), but this research highlights that further investment in broader mapping could significantly increase the availability of seabed data, which has the potential to realise new benefits by de-risking new investments in those areas.

[149] Department for Transport, 2015. Value for Money Framework. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/630704/value-for-money-framework.pdf

Likewise, the economic benefits from seabed mapping can vary year on year depending on global trade patterns and economic and policy conditions. Moreover, seabed mapping is likely to be more essential early in the development of activities (which is when economic output is low). Then as economic output increases and operations stabilise, other factors increase in importance and seabed mapping moves from being an essential component of establishing operations to being more of an ongoing cost (e.g. in maintenance). Many areas where there are benefits to be gained have already been mapped to modern standards but seabed mapping retains importance in terms of monitoring and maintenance; moreover, as the magnitude and breadth of uses of the seabed continues to increase, there is a constant demand for improved seabed mapping to realise future benefits.

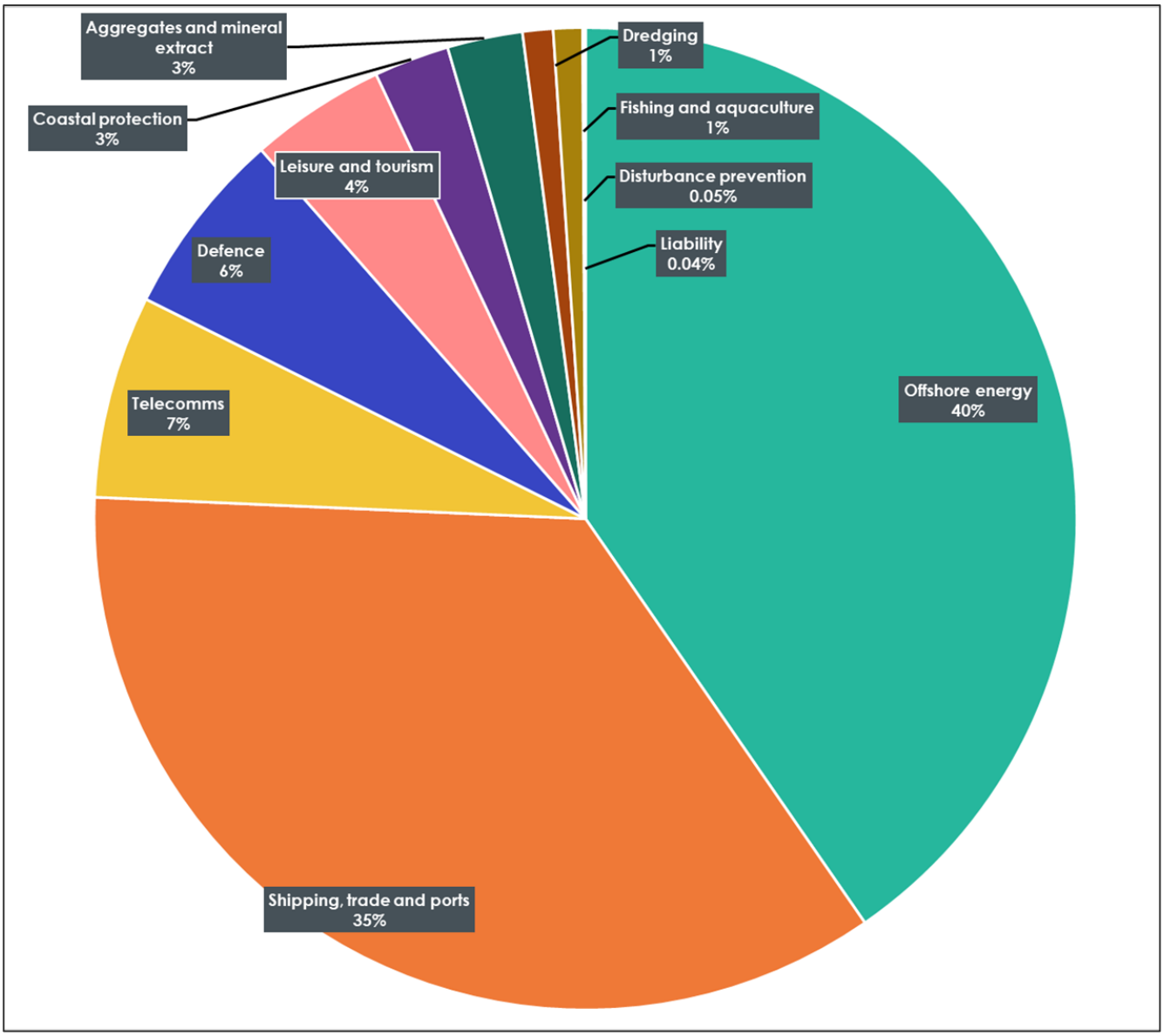
Some sensitivities were applied to this investment ratio to highlight how the magnitude of benefits varies under different scenarios. These are outlined in Table 16.

Table 16: Sensitivity of CBA

Sensitivity	Justification	New ratio
Removal of oil and gas sector	The cost benefit analysis ratio was recalculated with the economic benefits realised by the oil and gas industry removed, on the basis that this sector (and exploration and mapping of new sites) is unlikely to be a key area of growth for the UK in future given the UK's net zero commitments.	The ratio decreases to **£56** in benefits for every £1 spent on seabed mapping.
Removal of non-market values	The cost benefit analysis ratio was recalculated with the non-market values (such as environmental conservation and protection and climate change) removed, as the non-market valuations are less reliable than the market-based values, so it is useful to understand how the ratio changes without these figures.	The ratio decreases to **£83** in benefits for every £1 spent on seabed mapping.
Highest estimate of cost and lowest estimate of benefits	It is acknowledged that there is significant uncertainty in the calculation of benefits and therefore this sensitivity queries how the cost benefit ratio changes when the estimate of cost is at its highest possible range, and when the estimate of benefits is at its lowest.	The ratio decreases to **£33** in benefits for every £1 spent on seabed mapping.
Lowest estimate of cost and highest estimate of benefits	It is acknowledged that there is significant uncertainty in the calculation of benefits and therefore this sensitivity queries how the cost benefit ratio changes when the estimate of cost is at its lowest possible range, and when the estimate of benefits is at its highest.	The ratio increases to **£178** in benefits for every £1 spent on seabed mapping.

Figure 2 below provides a breakdown of the benefits from each sector that was included in the analysis.

Figure 2: Breakdown of Seabed Mapping Benefits



The majority of the benefits from seabed mapping stem from offshore energy and shipping, trade and ports, followed by telecommunications and defence. Though the value of the marine environment in terms of the ecosystem services that it provides is extensive, only a small proportion of this value can be attributed to or optimised by seabed mapping, hence the market impacts are significantly greater.

6.1 Optimising UK seabed mapping activities

This section provides commentary on how the CBA ratio could be further improved through identifying key themes from the stakeholder engagement and research into equivalent programmes. There is increasing competition for seabed space as the number of sectors competing for marine space and resources is growing, meaning that the need for mapping to ensure equitable and sustainable use of seabed resources remains critical. Use of the data varied between sectors; in the public sector seabed

mapping data is primarily used to fulfil regulatory requirements (with a primary driver being to ensure that SOLAS navigational safety standards are met) whereas in the private sector the data is primarily used to add clarity, reduce risk and improve efficiency for clients when making commercial decisions, and there are also a variety of non-profit actors and academic institutions using mapping data for research.

The lack of **application of consistent standards** generates inefficiency in the collection of seabed mapping data. The lack of standardisation in specifications appears to be widely acknowledged and the interviews suggest that the industry recognises the benefits of adopting standardisation. Though there are mapping standards (most notably the IHO's S-44 Standards for Hydrographic Surveys[150]) there are significant differences in quality required for different purposes – the precision required for ensuring navigational safety normally exceeds that for mapping habitats. Similarly some governmental departments have specific requirements for data quality to fulfil statutory reporting obligations. This leads to difficulties in sectors collaborating as there are different agendas. Establishing a consistent standard would enable data to be 'collected once, used many times' by increasing the availability of the data to more stakeholders.

Increasing **collaboration** between entities was also noted as a means by which to increase efficiencies and reduce costs, enabling greater spend on improved technologies or surveying new areas rather than replicating existing surveys. A lot of open-source data is available and used by numerous sectors but there are numerous authorities that contribute to maritime geospatial knowledge and no 'one stop shop'. The introduction of the 'one visit, many measurements' principle[151] could be applied to reduce the number of visits being taken (with associated environmental benefits of reducing diesel consumption and habitat disruption from surveys) and devising each visit to provide data that is relevant and beneficial for numerous sectors.

Similarly, a constraint on seabed mapping data collection noted by numerous stakeholders is **capacity**. Demand and fees for surveying contractors have grown. Competition has arisen both between UK sectors (with larger, more established sectors having greater leverage of capacity than smaller and/or emerging sectors) and internationally (one stakeholder mentioned that multiple survey organisations have moved to US operations). Whereas some public sector bodies have internal survey capability, most data users are dependent on hiring external contractors. This is particularly limiting for sectors that require data collection on a regular basis (e.g. tracking habitat change multiple times a year to detect seasonal variations) or where mapping is required for project progress (e.g. new surveys needing to be commissioned for offshore developments). Being able to undertake more frequent surveys would enable hazards (e.g. seabed landslides) to be identified and mitigated quickly. Additional funding could be utilised in the development of domestic capacity for provision of open-source, high-quality data.

It was also evident from stakeholder engagement that additional investment for improving data **quality** and **digital processing** would yield significant economic benefits. Much of the available open-source data was collected decades ago in a 'patchwork' manner, with discrepancies in data quality. A seamless, high-resolution dataset would yield benefits to numerous sectors (e.g. greater confidence to developers and investors) and enable prioritisation of future work. Investment in improved capability and improved quality would unlock increased accuracy and value.

6.2 Comparative studies

The importance of seabed mapping in enabling and enhancing maritime industries is widely recognised and maritime nations globally have established a variety of approaches to mapping their EEZs. This

[150] IHO, 2022. *Standards for Hydrographic Surveys S-44*. Edition 6.1.0. Available at: https://iho.int/uploads/user/pubs/standards/s-44/S-44_Edition_6.1.0.pdf
[151] Natural Resources Canada, n.d. *Seabed Mapping and Research Initiatives – Canadian Perspective*, Available at: https://www.marine.ie/sites/default/files/MIFiles/Docs/Comms/3.1.1LockeGalwayMay2013.pdf

section provides a comparative analysis and benchmark of results and conclusions reached in analogous studies, providing context and validation for the UK-focused findings.

- Deloitte undertook a research study in 2021 to ascertain the value of seabed mapping data in **Australia** to the blue economy. It estimated that the activities involved in producing seabed mapping data cost $51 million and produced $16 billion in direct ($9 billion) and indirect ($7 billion) value, which means that for every $1 invested, there is a return of $313. It further calculated that there is an additional $37 billion of unlocked economic activities that were enabled by the use of seabed mapping data during establishment, such as aquaculture and oil and gas, as the data is used in the formation but not ongoing operation.

- PwC undertook a research study in 2008 to ascertain the value of the INFOMAR Programme. The potential benefit of improving seabed mapping data was calculated for different sectors and the % impact was calculated to be (under the medium impact scenario) 2% additional growth for the fishing industry, 4% for aquaculture, 10% for the biodiversity and conservation sector, 20% for the renewable energy sector, 10% for the energy exploration sector and for the aggregates sector, in addition to benefits to the research collaborations sector of €2 million.[152]

- The International Hydrographic Organisation published a **global average** of the return on investment resulting from investment in seabed mapping in 2004 which calculated that the ratio was approximately 1:10.[153] This research focused on the benefits of nautical charting and the consequent impacts on maritime commerce.

- The **Secretariat of the Pacific Community** undertook a similar study in 2014 and calculated that the return from investment for the islands of Vanuatu was approximately US$91 for every US$1 invested.[154] This study included detailed calculations on the costs of undertaking the surveys and the benefits relating to the tourism sector (e.g. viability of cruise ships).

- **Seabed 2030** is a global initiative pursuing the goal of achieving a complete map of the ocean floor by 2030 to inform the UN's Sustainable Development Goal 14: *to conserve and sustainably use the ocean, seas and marine resources for sustainable development.* The initiative has outlined the method and sectors to be used in their benefit analysis model of the programme but the results are yet to be published.[155]

The ratio of cost to benefits to the UK from collecting widespread EEZ seabed mapping data to modern standards is higher than similar analogous studies undertaken in other nations or globally. This is likely due to the UK's mature marine environment and the density of economic activity taking place, which means that there is a wide range of infrastructure that has been invested in, which yields benefits from seabed mapping data. Moreover, this research includes the contribution of the private sector in addition to that of the public sector (aka governmental programmes) whereas many previous studies have focused on public sector cost and benefits.

[152] PwC, 2008. INFOMAR Marine Mapping Study Options Appraisal Report: Final Report. Available at: https://www.infomar.ie/rd-and-education/publications/infomar-marine-mapping-study-options-appraisal-report
[153] International Hydrographic Organisation, 2004. *Economic Impact of Hydrographic Surveys*. Available at: https://iho.int/uploads/user/pubs/misc/M2-Suppl/2010-Economic_Impact_of_Hydrographic_Surveys.pdf
[154] New Zealand Programme Pacific Regional Hydrography Survey and Maritime Charting, 2014. *Assessing the costs and benefits of hydrographic survey and charting a case study of Vanuatu*. Available at: https://pacific-data.sprep.org/dataset/assessing-costs-and-benefits-hydrographic-survey-and-charting-case-study-vanuatu
[155] Seabed 2030, 2023. *Phase 2 Objectives 4 & 5: Benefits Analysis Workstream Report Proposed model for Seabed 2030 – Seabed Mapping Benefits Analysis and Prioritisation*. Available at: https://seabed2030.org/wp-content/uploads/2023/06/20220617-Proposed-model-for-Seabed-2030-Benefits-Analysis-and-Prioritisation_Final-2.pdf

7.0 Conclusion

This financial cost benefit analysis of seabed mapping involved data collection, economic modelling, and quantitative analysis to derive an indicative return on investment ratio. There is significant uncertainty in the data used in this analysis as there is no single source of data on spend on seabed mapping (at either the public or private sector level) nor is there a clear method for attributing value of seabed mapping to each sector at different spatial and temporal scales. That being said, it is evident that the results of the CBA, with approximately £86 of generated value for every £1 invested in seabed mapping, are unequivocal on the significant economic and environmental benefits that could be realised through improving seabed mapping coverage to modern standards across the UK EEZ. The CBA captured the overall potential value, but it is evident that there are also other broader, cascading impacts to the UK's economy that are unlocked through seabed mapping which are not captured in the quantitative analysis. The direct and indirect impacts, where seabed mapping both enables and enhances the GVA of a sector, are substantial.

The benefits of investing in seabed mapping could be realised in multiple ways. It is important that this investment is delivered alongside standardised quality measures and mapping specifications as this can lead to greater value as mapping outputs can be used for a wider variety of applications. Finding a suitable specification based on internationally recognised IHO standards[156] that delivers appropriate quality for a range of users whilst not being prohibitively expensive to cover sufficient area is also critical. Growing the capability and capacity of the domestic seabed mapping and survey industry will assist in removing capacity-related barriers to increasing mapping activities, alongside investment in improved data processing. This should be accompanied by greater sharing of seabed mapping data between entities, which will further increase the cost-benefit ratio by reducing the expenditure on mapping. Focusing on coastal and maritime areas where market benefits are yet to be realised will simultaneously generate more equitable economic growth. Undertaking regular evaluation of the costs and benefits of improved mapping is recommended to enable comparison to cost benefit analysis studies for other sectors and to account for evolving seabed mapping technologies and for the value generated by emerging sectors.

[156] International Hydrographic Organisation, n.d. *Standards and Specifications.* Available at: https://iho.int/en/standards-and-specifications

Appendix

A.1.0 Interviewee sectors

Interview #	Interviewee sector	Organisation type
1	Maritime incidents	Public sector
2	Maritime incidents	Public sector
3	Defence	Public sector
4	Fishing and aquaculture	Public sector
5	General	Public sector
6	Offshore & coastal renewables	Public sector
7	General	Public sector
8	General	Public sector
9	Aggregates	Private sector
10	General	Both
11	Shipping, trade and ports	Public sector
12	Environmental conservation and protection	Public sector
13	General	Private sector
14	Oil and gas	Private sector
15	Offshore & coastal renewables	Private sector
16	Shipping, trade and ports	Private sector
17	Shipping, trade and ports	Public sector
18	Private sector mapping	Private sector
19	Private sector mapping	Private sector

A.2.0 UK Hydrographic Office as Primary Charting Authority for other nations

The UKHO operates under an obligation defined by SOLAS, focusing on mapping maritime routes, particularly shipping lanes. The UKHO is designated to fulfil this responsibility on behalf of the UK and extends its capabilities to provide similar services as the Primary Charting Authority (PCA) for other nations that do not currently have the ability to meet all of their obligations regarding safety of navigation. The UKHO is currently acting as PCA for 63 coastal states, including UK Overseas Territories, Commonwealth nations and several small island developing states in the Southwest Pacific, Caribbean, Indian Ocean, and South Atlantic.[157] One of the objectives of this research was to produce a flexible template and methodology that can be adapted for conducting analogous cost benefit analyses of seabed mapping in other regions where the UKHO serves as PCA.

By establishing a standardised template, UKHO can streamline and replicate the analysis process across different jurisdictions, facilitating a consistent and comparable approach to assessing the economic impacts of seabed mapping. This template allows for customisation based on the specific geographical context while retaining the rigorous approach to quantifying returns on investment across applicable thematic areas. This enables the efficient replication of studies to further build the evidence base and support continued investments in essential seabed mapping across UK jurisdictions. This effort supports the UKHO's overarching role in hydrography and reinforces its influence as a key authority in marine mapping initiatives.

The method used within this assessment is replicable for each of these locations, though there are likely to be specific considerations for each location. An overview of the broad steps is outlined as follows:

Step 1: Determine the scope of the assessment

The first task will be to determine the parameters of the assessment – this includes the geographic scope and activities to be included in the assessment. Given the aim to provide a consistent approach, the same sectors should be included in the assessment as those outlined within Section 2.0. There may be, however, other activities reliant on seabed mapping that are specific to the location being appraised. Therefore it is recommended that a scoping exercise is undertaken to ensure that all relevant activities are identified as the prevalence of each sector will vary in each nation.

Step 2: Costs of Seabed Mapping

The costs of seabed mapping will vary in each nation. The costs should include all public and private sector mapping activities. The sources of data will vary depending on location. For public sector costs, there is more likely to be publicly available data. For private sector costs, the data is likely to be derived from literature and interviews.

As outlined in Section 2.0, the costs should be presented as an annual average and multiyear programmes should be averaged throughout their duration. Costs should also be presented in real terms using a consistent price year.

Step 3: Benefits of Seabed Mapping

Understanding the economic contribution of the marine environment to these areas, and the value of improved seabed mapping is a vital step in the assessment. The first aspect of should be to identify the

[157] UKHO, 2023. *What is a Primary Charting Authority?* Available at: https://ukhodigital.blog.gov.uk/2023/10/23/what-is-a-primary-charting-authority/

economic contribution of the sectors. For some sectors, the activity will be well represented in national accounts. For others, however, the maritime aspects of the activity may be combined with activities which only take place on land. For example, the economic contribution of offshore wind is not presented separately to other energy generation activity that solely takes place on land (e.g. gas fired power stations). Therefore, a method of apportionment may need to be devised. This exact method is likely to be highly dependent on the availability of relevant data.

For non-market data, it is likely that the value of these aspects will be bespoke to the location being investigated. Therefore, it is recommended that bespoke research is conducted into each of these.

Once the economic contribution of the marine environment is established, the next aspect is to consider the attribution of seabed mapping. Given that many of the activities are likely to be similar to those in the UK, it was suggested that the same assessment criteria is used as presented in this report.

Step 4: Calculate the Cost Benefit Analysis. The final aspect of the assessment is to calculate the CBA ratio. This is derived from the data identified in step 2 and step 3.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