Centre for Environment Fisheries & Aquaculture Science

Cefas

Strategic Monitoring and Approaches: Setting Out a General Definition and its Application.

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Executive Summary

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) undertook a project for the Department for Environment, Food & Rural Affairs (Defra) focussing on what is meant by 'strategic monitoring' in the context of assessing the impacts of human activities on the UK marine and coastal environments. The main driver for this project was to develop an approach for implementing strategic monitoring of offshore wind and associated infrastructure development to better understand interactions, effects, impacts, and trade-offs within the marine and coastal environment for English (and Welsh) waters.

The study utilised a literature review, semi-structured interviews, and workshops to identify the key considerations for a strategic monitoring approach. These considerations were brought together into a set of principles and an overarching definition.

Following the agreement on the definition and principles (Task 1a), existing strategic approaches, not limited to monitoring, were reviewed covering regional, to national and international scales (Task 1b). These approaches were reviewed based on workshop attendees' direct recommendations of examples to the project team, as well as from a general literature search. The review of the approaches (Task 1b) determined if they met the definition and principles of strategic monitoring (from Task 1a) and assessed whether they could be used to support future strategic monitoring programmes.

The review of approaches identified that many strategic monitoring programmes meet some of the principles of strategic monitoring but not all. Whilst some of the existing approaches do not meet the criteria for supporting strategic monitoring, the data from these approaches would be useful in providing context for defining the current baseline and taking into account how baselines change.

From interviews and workshops, it was agreed that strategic monitoring is a complex topic, and the key is to develop a clear hypothesis or overarching research questions that target policy or change in the environment deemed meaningful (rather than just statistically significant) for any strategic monitoring programme. Once set out, and only at this point, should the monitoring then consider the next steps such as scale, analyses, and data (types and methods to collect). Other considerations have been discussed to help inform any future programmes.

It is recommended that the definition and principles proposed in this report are used as a basis for future strategic monitoring programmes and that the work be continued to develop a framework to set out structured and adaptable strategic monitoring programmes to aid marine managers.

Acronyms

ALB	Arm’s Length Body
BACI	Before-After-Control Impact
CCUS	Carbon, Capture, Utilisation and Storage
CEA	Cumulative Effects Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DAERA	Department of Agriculture, Environment and Rural Affairs
DAPSI(W)R(M)	Driver, Activity, State, Impact (on Welfare), Response (Management)
Defra	Department for Environment, Food and Rural Affairs
DPSIR	Driver, Activity, State, Impact, Response
DRIP	Data Rich, Information Poor
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIC	Environmental Industries Commission
EMAP	Environmental Monitoring and Assessment Program
EMF	Electromagnetic Field
FAIR	Findable, Accessible, Interoperable, Reusable
GIA	Grant in aid
GES	Good Environmental Status
GIS	Geographic Information Service
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IFCA	Inshore Fisheries and Conservation Associations
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
LCLP	London Convention/ London Protocol
MBES	Multibeam Echosounder
MMO	Marine Management Organisation
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NARS	National Aquatic Resource Surveys
NCC	Natural Capital Committee
NE	Natural England
ORJIP	Offshore Renewables Joint Industry Programme
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
OSW	Offshore Wind
OWEAP	Offshore Wind Enabling Actions Programme
OWEC	Offshore Wind Evidence and Change
OWEER	Offshore Wind Environment Evidence Register

OWF	Offshore Wind Farm
PAM	Passive Acoustic Monitoring
PBD	Pulse Block Days
RAG	Regional Advisory Groups
RLG	Regional Locational Guidance
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SSC	Suspended Sediment Concentrations
UKMS	UK Marine Strategy
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WGNAS	ICES Working Group for North Atlantic Salmon
YFS	Young Fish Survey

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1. Strategic Monitoring: Developing a Definition (Task 1a)

1.1. Background

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) undertook this project for the Department for Environment, Food & Rural Affairs (Defra) focussing on what is meant by ‘strategic monitoring’ in the context of assessing the impacts of human activities on the UK marine and coastal environments (project brief in Appendix I). The main driver for the project was the need to develop an approach for implementing strategic monitoring of offshore wind and associated infrastructure development to better understand interactions, effects, and trade-offs within the marine and coastal environment for English and Welsh waters. This report first proposes a definition of ‘strategic monitoring’ informed by literature, semi-structured expert interviews, and expert and stakeholder workshop engagement (Task 1a; Sections 1 and 2). The report then uses the definition as the foundation on which to build key principles and recommendations for developing a strategic monitoring approach, informed by a review of existing approaches both from the UK and internationally (Task 1b; Section 3).

The wider context of the project is for the definition, principles and recommendations proposed to be used as a basis for developing an adaptable and robust strategic monitoring approach, which can be applied in the future to formulate a framework for strategic monitoring programmes to aid marine managers.

For further background context on the project, see Appendix I.

1.2. Methods

1.2.1. Literature review

A general, non-comprehensive review of the primary and secondary literature was undertaken, including literature recommended during expert reviews and expert and stakeholder workshops. The objective was to collate existing definitions of ‘strategic monitoring’ from the literature and then incorporate the perspectives of experts and stakeholders to draw out the main concepts on the topic. Literature was searched using Clarivate, Web of Science and Google Scholar.

1.2.2. Expert semi-structured interviews

To arrive at the general concepts that should be included in a definition of strategic monitoring, the first step was semi-structured interviews conducted with Cefas experts in a range of relevant fields. For more details, including a list of Cefas interviewees, see Appendix II. The interview questions were shared with the experts ahead of the interview, with the responses varying from emailed responses through to topical discussions and associated notes. Appended to the interview questions was a request to share or direct the review team to any relevant literature, which was consulted along with any other related literature that was deemed relevant.

1.2.3. Expert and stakeholder engagement workshops

Following the review of definitions and the Cefas expert interviews, two Defra-led workshops were organised to obtain feedback on the proposed draft definitions of “strategic monitoring” and subsequently updated. For more details of the workshops, including a list of participant organisations, see Appendix II.

1.3. Defining “strategic monitoring”

1.3.1. First draft definition

Based on the review of the literature and interviews with Cefas experts, a first draft definition of “strategic monitoring” proposed was:

> *strategic monitoring assesses changes in the socio-economic and environmental status of the spatial and temporal domain potentially impacted, positively or negatively, by human activity to allow effective adaptation to, and mitigation of, any undesirable impacts.*

This proposed definition incorporated the main concepts encountered during project research that are suggested to underpin *monitoring*, and how it is done *strategically* (Figure 1).

This first draft definition was supported by the literature review and was shared with Defra and representatives from its Arm’s Length Bodies (ALBs) and then with a wider project Steering Group for their consideration and comment. See Appendix III for group member organisations and dates. After each meeting, the definition was revised to address the comments received, as too was the associated literature review, presented in Section 3.

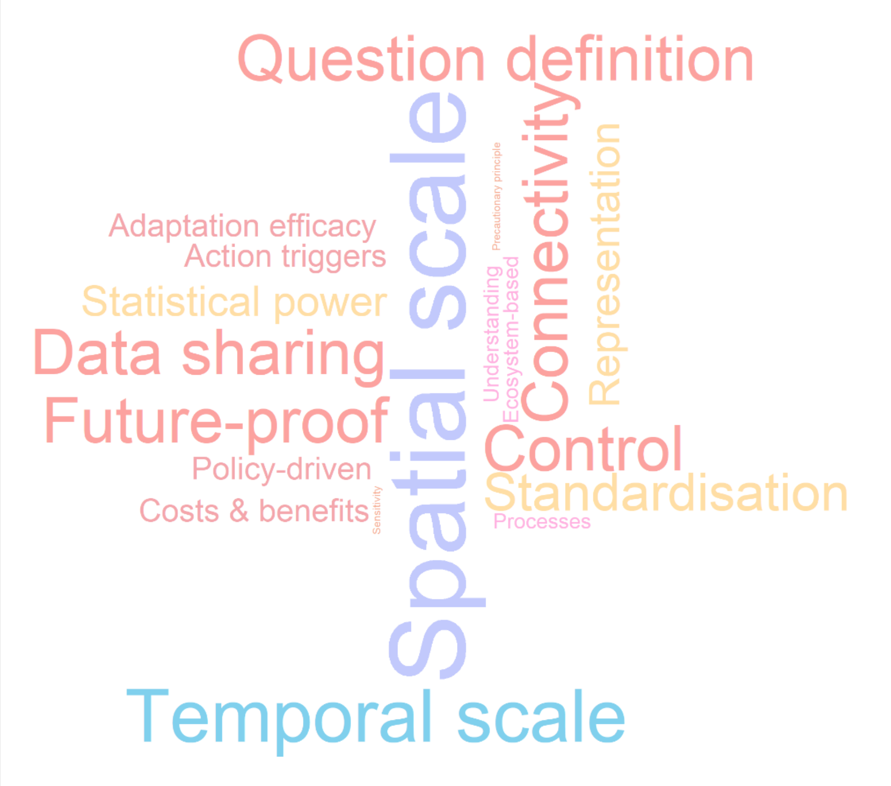

Figure 1 A word cloud showing concepts encountered during interviews with experts towards a proposed definition of strategic monitoring.

1.3.2. Revised strategic monitoring definition

Following both workshops there were a range of comments provided. The draft definition was revised accordingly, with the main agreed comments being:

- The definition should include concepts that make it more clearly strategic, to include:
    - presenting it as a principle
    - promoting collaborative working and
    - making allowances to fill knowledge gaps
- Cumulative impacts should be considered with negative and positive impacts.
- Decision-making should be proportionate.

Summary notes of the meeting that provide further background to the definition discussion are included in Appendix III. The updated strategic monitoring definition is given in Figure 2.

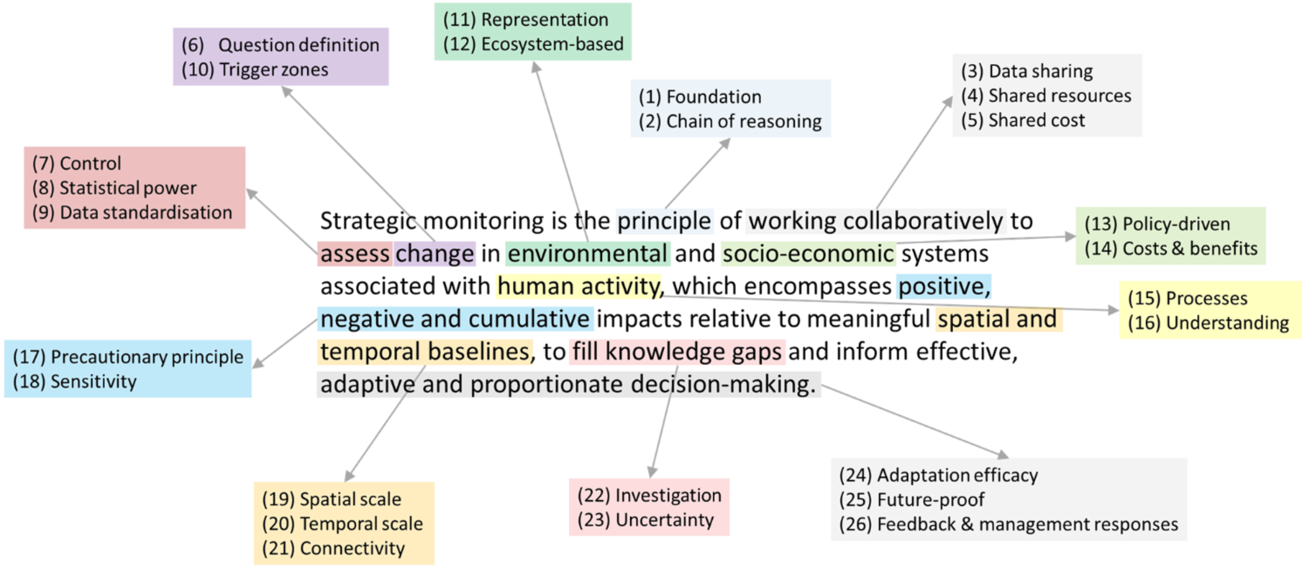

Figure 2 Revised strategic monitoring definition incorporating comments from expert and stakeholder engagements. The colour-coded boxes link concepts to specific terms used in the definition. The numbers link the concepts to the summary text below.

The following section summarises – with reference to the primary and secondary literature – why these concepts are important to the revised definition of strategic monitoring with reference to specific terms within the definition (see Figure 2).

1.4. General concepts

1.4.1. Monitoring

Monitoring is centred around three main *concepts* and is "to *watch* something *over a period of time* in order to see *how it develops*, so that you can "*make any necessary changes*"[1]. These main concepts are captured in most definitions of monitoring used to detect changes in our natural world. For example, a recent report of the International Union for Conservation of Nature (IUCN) Species Survival Commission Species Monitoring Specialist Group and the IUCN Global Business and Biodiversity Programme defines monitoring as "*the periodic collection and evaluation of data relative to stated project goals and objectives" and in accordance with a monitoring plan that "includes information needs, indicators, methods, timeframe and roles and responsibilities for collecting data*" (Stephenson & Carbone, 2021). Similarly, a definition of monitoring in the marine environment adopted by OSPAR is "*the repeated measurement of: (a) the quality of the marine environment and each of its compartments, that is, water, sediments, and biota; (b) activities or natural and*

[1] Oxford Learner's Dictionary of Academic English

anthropogenic inputs which may affect the quality of the marine environment; (c) the effects of such activities and inputs" (OSPAR Commission, 1992).

1.4.2. Strategic

For something to be considered as strategic it should "*be done as part of a plan* that is meant to *achieve a particular purpose* or to *gain an advantage*"[2]. Faced with questions over what, how, where, and when to monitor, while considering that priorities differ, knowledge is incomplete, and resources limiting, it would seem sensible that monitoring plans are based on strategies to maximise their effectiveness, i.e., strategic. In the marine context, the definitions identified in Section 1.4.1 from the IUCN and OSPAR can be applied at the strategic level.

Of note , and a common theme throughout the following sections, is that strategic monitoring is closely related to project specific monitoring, in fact meeting the objectives of strategic monitoring will likely require a series of targeted project specific monitoring. As such, many of the steps and considerations are the same i.e., defining research question. What makes strategic monitoring different to project specific monitoring is the scale and scope of the research question and the requirements to answer such a question. For strategic monitoring we generally need larger spatial scales, longer time scales, the ability to be adaptive in response to the drivers of the strategic thinking and the need to bring different datasets and evidence together to enable decision making. These elements are reflected in the definition.

1.4.3. Combining outputs to define strategic monitoring

In the following text, points relating to concepts and terms highlighted in the colour-coded boxes in Figure 2 are shown in bold and can be cross-referenced by their corresponding number in brackets, e.g., ***future-proof*** *(25).*

Based on the literature review and consultation with the Defra/ALB's and project Steering Group, it was agreed that "strategic monitoring" should be regarded as a principle. Accordingly, it should be considered a **conceptual foundation** (1) with an associated **chain of reasoning** (2) that those wishing to do strategic monitoring must follow to ensure all concepts in the definition are taken into account. In other words, a monitoring programme would only be considered strategic if it was aligned to the concepts used in the strategic monitoring definition in Figure 2. By treating "strategic monitoring" as a principle to which practitioners should adhere, the concept of working collaboratively can be more easily achieved. Specifically, following a prescribed principle would allow promotion of ideas underpinning collaborative working, such as **data sharing** (3), **shared resources** (4)(e.g., survey vessels and equipment), and ultimately **shared costs** (5) (Cooper *et al.*, 2019).

[2] Oxford Learner's Dictionary of Academic English

Careful **question definition** (6) was widely recognised as a critical consideration when designing a monitoring programme to detect change (Allan *et al.*, 2006), i.e., what is the question you want strategic monitoring to answer? Detecting change is challenging when that change happens within an environment that is also changing, whether naturally (van Meyel, 1979) or because of other human activity (Wilding *et al.*, 2017a). Related – largely statistical – concepts were also encountered, including the need for **control** (samples or reference sites) (7) and **statistical power** (8) in order to assess the magnitude and relevance of any detected changes (Sutherland, 2006). For example, a 10% change in abundance of a population that varies in abundance naturally by 10% each year would be difficult to detect over a few years and could be more difficult if the abundance was also declining (Lande *et al.*, 2003). A reduction in variability could be achieved through **data standardisation** (9) of bringing together disparate datasets into a common format to allow integration and or comparison. If change is detected relative to agreed baseline(s), it was recognised that action(s) should be considered when approaching or within predefined **trigger zones** (10). These are needed to ensure that action(s) are initiated in time to respond to any change, whether it be a negative impact that should trigger remedial action(s), such as mitigation or compensation, but also a positive impact that might trigger opportunities.

An often-quoted phrase is that ‘the only constant is change’ i.e., variability is inherent in all systems, from those of the natural environment, such as ecosystems, to human concepts, such as societies and economies. Each of these systems has myriad complexities. For example, a single ecosystem can encompass millions of organisms, their interactions and feedbacks with one another and their environment, and any emergent effects (Brook *et al.*, 2008). Rather than try to monitor even one of the complex systems, we tend to monitor agreed indicators to represent them (McQuatters-Gollop *et al.*, 2019). Several respondents highlighted the need to ensure indicators were a good **representation** (11) of these complex systems and that taking an **ecosystem-based** (12) approach to monitoring is important to allow for interactions among multiple indicators.

It was agreed that strategic monitoring should be policy driven (13). Specifically, it was suggested that strategic monitoring should be implemented to meet policy requirements, which are set by governing bodies and assumed to reflect the people’s priorities. It was also raised that any strategy would have to account for possible **costs and benefits** (14) to different systems, including socio-economic systems, but also environmental and ecological systems that might gain from some human activities, such as no-fishing zones within and around offshore wind farms (Gill *et al.*, 2020a).

Experts and stakeholders emphasised the need to consider how human activities might affect the system **processes** (15), rather than just the patterns of change, and these should reflect prevailing **understanding** (16) of these systems. Where there are knowledge gaps or understanding is lacking, it was suggested that provision for additional, more focused monitoring would be beneficial and with consideration of the statistical basis for the monitoring (Wilding *et al.*, 2017).

A few respondents raised issues around dealing with uncertainty in assessment of change. It was suggested that it would be prudent to adopt the **precautionary principle** (17) and trigger mitigation unless no impact could be proven beyond reasonable doubt. Another suggestion was that the **sensitivity** (18) of the assessment outcome could be explored by varying the inputs to the assessment, a so-called sensitivity analysis.

The ability to assess change due to a single human activity is complicated because they rarely occur in isolation, whether it be multiple instances of the same activity or other additional activities (Borja *et al.*, 2010; Wilding *et al.*, 2017a). Assessing changes due to multiple developments requires a cumulative effects assessment that is "*a systematic procedure for identifying and evaluating the significance of impacts from individual or multiple sources and/or activities*" (Lonsdale *et al.*, 2020). Understanding of the need to look beyond the **spatial scale** (19) and **temporal scale** (20) of the domain potentially impacted by a human activity was widely recognised in the review (Wilding *et al.*, 2017a). Associated ideas were also recognised, such as **connectivity** (21), whether in space use by indicator species or between proposed activities to improve collaborative working (Stephenson & Stengel, 2020).

While one can monitor aspects of the environmental and socio-economic systems that are known about, there always exists the possibility that there are aspects of those systems that are unknown but that become apparent during the monitoring. In cases such as these, and where they are deemed to be important, it was agreed that strategic monitoring should aim to fill knowledge gaps by making allowances for additional **investigation** (22) to learn more or to reduce **uncertainty** (23) in our understanding of systems and their processes or our characterisation of them.

Notwithstanding issues around assessing change in representative indicators, its effect on these complex systems and when action should be taken to limit their impact, it is important to consider whether any remedial action(s) will be effective now and in the future (Lindeboom *et al.*, 2015a). These concepts were recognised among respondents, especially the need to monitor the systems response to actions to maximise **adaptation efficacy** (24) (how quickly we can implement adaptive management/ measures) and ensure that monitoring programmes and their attendant actions are **future-proof** (25). This would also include potential for **feedback & management responses** (26) to ensure actions and decisions are effective for all.

1.5. Advantages of strategic monitoring

Overall, the research outputs – taken together with the prevailing opinions of experts and stakeholders – concluded that adopting strategic monitoring (or a strategic approach to monitoring) would have advantages compared to the variety of disparate approaches currently undertaken. Among the most important perceived advantages to adopting strategic monitoring were the potential to reduce activities that result in a "data rich information poor (i.e. DRIP)" situation (Wilding *et al.*, 2017), and the possibility to move away, albeit not wholly, from individual plan/site assessments and towards a programme of coordinated and collaborative regional monitoring with its perceived improved efficiencies and with the aim that localised issue specific monitoring when integrated with other types of monitoring (and locations) can be used at the strategic level. Furthermore, it should address knowledge gaps that have been identified and justified as important to further our knowledge and understanding of the environment and the effects of human activities upon it (such as OSW development in the coastal and marine environment). It should be noted that a more strategic approach to monitoring will likely include both strategic monitoring (e.g. monitoring at an appropriate scale) and project specific monitoring depending on the receptor e.g., marine mammal distributions are more well suited for strategic monitoring whereas localised impacts would be at the project level, which should be able to feed into the strategic objectives.

2. Background to strategic approaches

To begin the process of determining the key elements for a UK applicable and effective strategic approach in the future, the project team held an internal (Cefas) workshop. Each of the 17 attendees had previous technical and or project lead experience of monitoring approaches covering a broad range of scientific interests. The list of attendees and their specialisms are provided in Appendix IV. The workshop was held virtually via Microsoft Teams for half a day on the 25th April 2022. The agenda and the pre-workshop information are provided in Appendices V and VI respectively.

2.1. Internal Cefas Workshop

The objectives of the workshop were to:

- Ensure the development of a suitable Strategic Monitoring approach captured key points.
- Ensure key considerations were captured in the designing of a strategic monitoring programme.
- Capture projects or approaches that are useful or can contribute to strategic monitoring for inclusion.

The workshop was split into four sessions:

i) Introductory presentation to the project and workshop objectives.
ii) Breakout Session 1, where attendees were asked to feedback what are the key considerations when developing a strategic monitoring programme.
iii) The considerations from Breakout Session 1 were summarised and the attendees were asked to vote on the most important.
iv) Breakout Session 2, where each group took one of the key aspects from the voting in (iii) and discussed in more detail.

The Breakout Sessions each had three breakout groups, with two facilitators (with appropriate expertise for the topic). The breakout groups each attendee was assigned to is summarised in Appendix IV. The notes of the discussions are provided in Appendix VII.

2.1.1. Breakout session 1

Workshop attendees were split into three separate breakout groups broadly based on similar expertise and/or backgrounds, e.g., freshwater fishery scientists were placed in Group 3. All groups considered a guiding list of questions to facilitate discussion. These questions were not intended to be exhaustive, and discussion in all groups led to a range of more general comments or feedback not covered by any of these questions. On completion of the first breakout session, group facilitators consolidated all comments to inform development of options for a subsequent Slido[3] poll.

The questions provided for review were:

- What data sets need to be included in the strategic monitoring review?
- What adaptations do we need to make to these sources in order to make them more valuable for strategic monitoring purposes?
- What are the key questions for offshore wind that Strategic Monitoring needs to/can address?
- Are there any data sets which could be combined to be more valuable for strategic monitoring?
- What areas need further consideration?
- What are the gaps in available data?

In the discussions it was agreed that there are a lot of data sources, such as fish landing data, VMS, marine mammal observations, seabird monitoring data. Therefore, it would be better to consider what the overarching hypothesis/es is/are and then carry out a data mining step. This latter step should be used to determine if any data are being collected and their appropriateness to addressing the hypothesis/es. Additionally, data from earth observation (e.g., sea surface temperature or chlorophyll A available from Copernicus.eu[4]) and outputs from ocean process models (e.g., ocean currents or winds available from the Met office[5]) would more likely be needed in the future to address the spatial resolution often talked about for strategic monitoring (a key part of the definition in Figure 2). It was noted that bringing all the data together would be a challenge.

There was also discussion about bringing in wider elements of the marine environment beyond pure ecological receptors to include and consider ecosystem services and marine natural capital. There are a lot of project outputs being generated at present where these would be relevant and transferable.

Other suggestions, specific to offshore wind farms were discussed, such as using the infrastructure as platforms to collect additional data on a strategic level across an offshore wind array or across multiple arrays. This could include passive samplers attached to turbine foundations or installing a network of monitoring buoys to collect data at the right scale. A key question for stakeholders will be to consider what an acceptable level of impact, either adverse effect on a defined receptor, or positive outcome or environmental benefits (as not

[3] Slido is a web-based audience interaction tool for meetings and events. It can be used to ask questions both of the presenter but also the audience and gain views either anonymously or attributed.
[4] https://www.copernicus.eu/en
[5] https://www.metoffice.gov.uk/weather/learn-about/weather/oceans/ocean-modelling-for-marine-forecasting

currently allowed under The Conservation of Habitats and Species Regulations 2017), such as displacement of trawling and increasing abundance of species within a wind farm due to acting as a refuge. This also has complexities as for instance, managing MPAs for carbon and biodiversity do not necessarily correlate; high carbon may not mean high biodiversity and vice versa, or even be linked.

2.1.2. Voting

Of the 58 total notes captured in the Breakout Sessions, the facilitators summarised the points into eleven key themes. Each participant then voted for the three options they considered to be the most important (3 votes per participant), the results of which are presented in Figure 3. Overall, 'Defining the Question' was deemed the most important, followed by 'Scale Trade Offs' and 'Integration of Data'. Note that 'Scale Trade Offs' covered temporal and spatial scales.

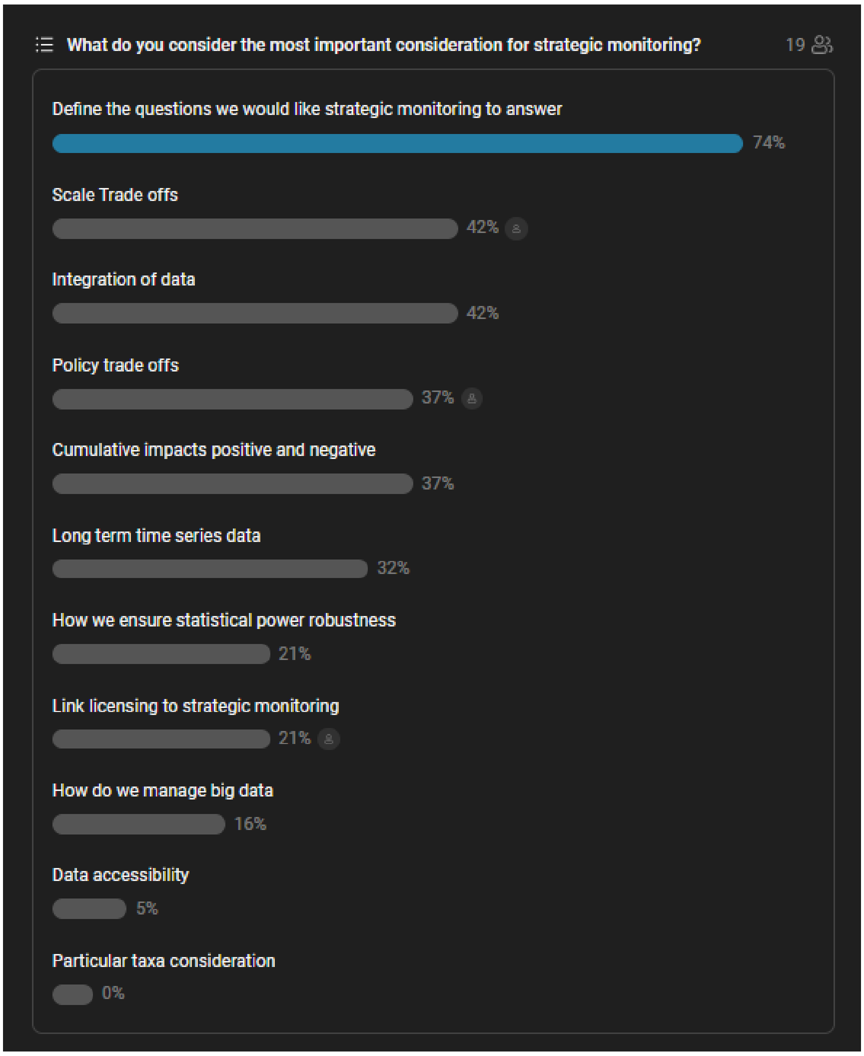

Figure 3 Results of the voting carried out on the considerations for strategic monitoring to determine the importance.

2.1.3. Breakout Session 2

For Breakout session 2, each of the three groups identified in session 1 were assigned one of the top three considerations resulting from the voting. Each group then brainstormed their respective consideration point, the results of which are given in Appendix III.

Breakout Group 1 – Define the question we would like strategic monitoring to answer

All breakout groups for both sessions reiterated the point that defining the question to be answered (i.e., the hypothesis or research question) is key. Without this, we cannot define the temporal or spatial scale, understand the analyses that should be undertaken and therefore what data are needed for the analysis.

There are two approaches: specific or more general. For example, an attendee noted that an offshore wind farm may be developed in an area of important carbon stock[6] (for example trenching the seabed for cabling laying and releasing stored carbon), but carbon is not monitored either consistently nationally, or ever at the site level. Therefore, it was felt that strategic monitoring must overall be about understanding the full effects of a development, not from just one sectoral policy or evidence area. However, it is noted that it is not possible to understand all the effects and therefore, again the research question being answered (the 'so what') is critical to define first and foremost. Furthermore not all impacts will be identified at the scale of a strategic monitoring resolution, rather the aim should be to integrate project level monitoring, that can determine local scale changes, into a larger strategic monitoring programme.

As with other groups and sessions, the question regarding who will pay for these strategic monitoring programmes was raised: depending on the budget, the programmes could vary in terms of spatial and temporal scale and levels of confidence in answering the hypothesis. To help with this, it was suggested that it is important to have a baseline understanding of 'what areas are important for' to avoid impacting something without knowledge.

Breakout Group 2 – Scaling trade-offs

As per Break out Session 1, there was discussion regarding the use of sentinel stations (i.e., equipment that can take measurements autonomously and transfer the data back to land for analysis) that could measure multiple parameters at the same location to gain the longevity of data time series to inform trends over time (temporal trends). This was considered important to provide data towards ecological and/or ecosystem understanding and modelling, which was regarded as not being fully addressed through the single receptor/ impact approach currently employed on a site-by-site basis. However, any new development that could have a zone of influence overlapping with such stations could affect this time

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[6] Carbon stock here is used here to define areas of the seabed that store carbon and thus contribute to climate change mitigation/ reduction.

series and therefore, careful planning is required: do we prevent any further development in these areas or note this additional influence in the timeseries?

The attendees noted that whilst an ecosystem-based monitoring[7] approach is required, there is agreement that it is not possible to monitor everything and as such a risk-based approach is required, linked to confidence levels. Again, the need for a clear hypothesis or research question was highlighted as the level of risk and level of confidence will change depending on the scale being investigated and the defined impact level. As such it was questioned whether there could be acknowledgement that, for instance, acute noise impacts are typically predicted to be significant during the construction phase of a fixed offshore wind farm but are regarded as lower during operation. However, during operation the consideration should shift away from acute noise impacts to the potential for longer term, chronic impacts, which may require different monitoring considerations. Therefore, temporal, and spatial scales will also have different risks that need to be considered. Equally important is who reviews the hypotheses for appropriateness as there should be processes in place to avoid bias across disciplines.

Breakout Group 3 – Integration of data

A range of points were raised regarding the design and implementation of data integration. Critical, early-process points were:

- It is essential to identify the purpose of individual datasets, as there may be conflicts between the data needs of a policy customer/regulator compared to a science organisation. In this regard, it is important to determine how different stakeholders would approach a strategic monitoring proposal to align priorities and harmonise any data collection.
- Planning for data collection should always begin with identifying all relevant data sources first, then determining what level of engagement should be conducted in terms of incorporating these data into any central resource or programme

A focal point of discussion comprised the practicalities of integrating multiple, large-scale, multi-year datasets. Key points were:

- Who should be the convener or “broker” of such a high-level data and monitoring programme or resource?
- Transparency initiatives are already in place at multi-lateral level regarding multiple datasets/monitoring programmes. One example is the ICES data unit in their

[7] Ecosystem-based management (EBM), and by extension, monitoring, is an integrated approach to management that considers the entire ecosystem, including humans (from https://link.springer.com/referenceworkentry/10.1007/978-94-017-8801-4_41)

approach to consolidating fisheries stock assessments, from which various lessons could be learned

- Data quality must be maintained and/or measured, therefore who would be responsible? With potentially many different stakeholders providing data, there is the potential for a range of data quality to be present in any consolidated resource. Should consideration be given to weighting different data sources?
- There exist many large-scale programmes and groups focussed on the sharing and integration of data, such as MEDIN and EMODNET. It is important to consider how these would be incorporated into any strategic programme and in particular those data which were provided to the programmes from third parties.

2.2. Workshop Concluding remarks

Ideally, the management of human activities would incorporate knowledge across all active marine industries at a spatial and temporal scale relevant to natural variability in environment components potentially affected and potentially impacted (for example, considerations of spatial prioritisation within marine planning). Similar recommendations have been made before. For example, Tidd *et al.* (2015) demonstrated that decision-making by fishers is affected by the real-time presence of other sectors in an area and therefore needed to be accounted for in marine planning.

The key and recurring points raised in the workshop were that defining the hypothesis/es or research question(s) is the first step, before moving onto considering the spatial and temporal scales, the data required and the analyses to apply. There are multiple approaches that could be taken (summarised in Appendix IV). The key points that should be considered in any future strategic monitoring programme are summarised in Figure 3. The methods for data collection, such as for environmental benefit assessments, and sentinel monitoring approaches were also regarded as important points. Through the workshop and semi structured interviews attendees also provided examples of strategic monitoring that are included in the review of approaches.

3. Strategic Monitoring: a Review of Approaches (Task 1b)

3.1. Background

Through the literature review and expert consultations outlined in Section 1, it was agreed that strategic monitoring can be defined as:

> *strategic monitoring is the principle of working collaboratively to assess change in environmental and socio-economic systems associated with human activity, which encompasses positive, negative, and cumulative impacts relative to meaningful spatial and temporal baselines, to fill knowledge gaps and inform effective, adaptive, and proportionate decision-making.*

While it was agreed that this definition captured the main concepts underpinning monitoring, and how to do it strategically, it is important to contrast it with already established strategic monitoring definitions and programmes from other sectors and nations. This section presents a review of existing approaches to strategic monitoring both in the UK and internationally.

It should be noted that this review is not meant to be an exhaustive list of all strategic monitoring programmes currently being undertaken. Rather, select approaches have been reviewed to provide examples of what successful strategic approaches look like and how data could be used for future strategic monitoring approached.

3.2. Overview of strategic monitoring principles

To set it apart from a non-strategic monitoring programme, a strategic monitoring programme should meet the principles identified in Section 1. These are:

1) **Policy-driven:** The programme should be informed by, and align with, national and international policies designed to capture public priorities for the natural environment, such as its protection or exploitation.
2) **Collaborative:** Aspects of the planning, and perhaps the implementation, process should be approached collaboratively, encouraging good practices such as data standardisation and sharing, while maximising efficiency and minimising costs.
3) **Spatially and temporally resolved:** By approaching assessments collaboratively, they are done at spatial and temporal scales meaningful to the indicator, rather than at potentially suboptimal scales constrained by logistical considerations; and

4) **Adaptive with feedback:** Planning, implementation, and management are all subject to feedback to maximise the probability that they are effective and efficient. This step also should have the programme reflect on the conclusions to date and consider if further monitoring is required (either as is or modified) or can stop if the question has been answered.

In this context, an ambitious and multinational example of a strategic approach to monitoring the environment is the Global Environment Outlook, coordinated by the United Nations Environment Programme (UNEP) and the latest issue of which is the Global Environmental Outlook 6 (https://www.unep.org/resources/global-environment-outlook-6). The report includes details of the process undertaken to make the assessment, from identifying the pressures on the environment to reviewing its state, and then reviewing the policies, goals, governance, and measures needed to ensure good environmental condition. The principles of a strategic monitoring programme are highlighted throughout the report. It emphasises the need for policy-driven environmental decision-making that builds on collaborative working within and between sectors and across issues, including social and economic. It also highlights some of the impediments to instituting long-term policy changes, thereby fulfilling the requirement to incorporate useful feedback. Interestingly, the Global Environmental Outlook 6 is based on a Drivers, Pressures, State, Impact & Response (DPSIR) approach.

3.2.1. Sample collection, processing, and analysis

In addition to fundamental principles, a crucial component of any monitoring programme designed to describe the state of the environment, and measure the impact of human activities upon it, is the consideration of why, what, how and how many samples will be collected, processed, and analysed to achieve those goals.

The 'why' of sample collection is perhaps the most important consideration of any monitoring programme, because it underpins the 'what', 'how' and 'how many' sample collection considerations. If the aim is to describe the state of the environment, then it might be sufficient to use our knowledge of the system to take representative samples of the environment. However, this assumes that our knowledge of the system is complete and accurate. Environmental systems are complex with myriad species and ways that they can interact with one another and their environments. Consequently, it is unlikely that our samples can ever be truly representative of the system. Rather, they will represent the system at a particular point in space and time, even if they are collected at large spatial and temporal scales. For example, environmental systems can undergo regime shifts whereby they change irrevocably from one state to another (Beaugrand, 2004). In such cases, any samples taken before the regime shift will no longer be representative of the system. Regime shifts can be caused not only by single influential events, such as a volcanic event, but also by gradual changes through time, such as climate change. If the aim is to measure the impact of human activities on the environment, then we must also consider the effects of additional human activities, their synergic effects, and the baseline state against which to measure change (Underwood & Chapman, 2013). However, this assumes that we can understand fully the additive, interactive and cumulative effects of individual and multiple human activities on the environmental so that we can represent them properly. This is likely unfeasible and as such perhaps rather than trying to measure everything, we consider that knowing ‘why’ something is happening/ changing is sufficient. For example, our understanding of the effects of an offshore windfarm development on the fish community at a site will likely change as the site conditions and fish community change with global warming and understanding the driver of the change is important to inform management. Ultimately, without a thorough understanding of ‘why’ sample collection is to be done, there is a risk that the sample collection could result in DRIP data. However, models can also be used to take DRIP-y data and provide the mechanisms to increase informativity, provided they are suitably calibrated and validated.

The ‘what’ of sample collection must consider the ecological process(es) that are to be characterised. For example, if we want to know how a particular offshore windfarm development might affect the fish community at the site, then we will want to collect data on the occurrence, distribution and abundances of the different fish species using that area. However, the apparent simplicity of this task belies the substantial complexity of collecting data to represent such a dynamic system. Fishes are a diverse group of species, each with their own seasonal- and life-stage- specific space and habitat requirements, prey and predators, behaviours that affect their catchability, physiological preferences, and tolerances, and so on. These considerations raise questions over what spatial and temporal scales samples must be taken to ensure that the samples are truly representative of the fish community at the site.

The ‘how’ of sample collection must consider the costs and benefits of using different methods to collect the samples. Different sample collection methods have different inherent biases (often called “selectivity”), and these will depend on the behaviours of the organisms being sampled. For example, it is unlikely that a grab sample will collect the same species as a bottom trawl, and neither method will likely collect a sample representative of organisms that spend most of their time near the water surface. Using a range of sampling methods chosen to minimise their inherent biases for individual species could be the best option but could also be a financially expensive option.

The ‘how many’ of sample collection must consider the spatial and temporal variability in the metric that the samples are collected to characterise, such as the fish community measure, and how that relates to the number of samples needed, and the ‘why’ of the sample collection. In general, variability in data decreases as the number of samples taken to create it increases (Underwood & Chapman, 2013). As variability decreases, so too does the chance of drawing spurious findings from the samples. While this might indicate that maximising the number of samples would be a good default position, it is possible that increasing sample size no longer improves the answer, as was shown by the CAMPUS project (see Section 3.6.1). Rather, it is more cost-effective to undertake a 'power analysis', which is a statistical procedure designed to guide decisions about sample collection given an understanding of the 'why' of sample collection and the expected characteristics of the resulting data, such as their spatial and temporal variability and the level of change expected from any impact of human activity (e.g., package `emon`[8] for the open-source statistical language `R`[9]; Barry *et al.*, 2017).

Processing collected samples should be done in a standardised – and therefore replicable and repeatable – way to minimise errors and maximise comparability between data and subsequent analyses. To be more strategic in their approach, monitoring programmes should look for opportunities to share information, and thereby sharing costs. In other words, working collaboratively could be financially rewarding, as well as guarding against drawing spurious findings or findings at spatial and temporal scales not representative of the impact being measured (Wilding *et al.*, 2017a). There are initiatives that promote the standardisation and sharing of environmental monitoring data (e.g., the Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy Sharing Environmental Monitoring Data proposal[10]), and indeed agreements with The Crown Estates require that data are submitted to the Marine Data Exchange, however they can be limited by their commercial interest and importance. Yet, some existing and effective strategic monitoring programmes, such as those under development in the aggregate extraction sector (Cooper & Barry, 2017a), have already demonstrated the advantages of data standardisation and sharing, including better assessments of any impacts to the natural environment.

If the 'why', 'what', 'how', and 'how many' questions of sample collection have been resolved and the data are standardised and shared, then the final step of analysing the data to measure the impact of any human activity can be relatively straightforward, since statistical models used for such purposes are widely available and user-friendly. Interpreting the results from such statistical models should be done with care and will – in part – reflect the understanding of the system that was sampled. Consideration must be given to whether the results are both accurate and precise, i.e., that they capture the direction and strength of the impact with an associated uncertainty that allows for their unambiguous interpretation; if they are either inaccurate or imprecise, then the 'what', 'how' and 'how many' questions of sample collection must be revisited. Care must also be taken to ensure that the statistical models are robust by exploring their diagnostics, which depend on the statistical model used, but should be explained in the user information for the software used.

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[8] https://CRAN.R-project.org/package=emon

[9] https://www.r-project.org

[10] http://www.orjip.org.uk/sites/default/files/ORJIP%20Ocean%20Energy%20%20Sharing%20Environmental%20Monitoring%20Data%20V2.pdf

Finally, reporting of impacts of human activities (including a lack of impacts) against licence conditions, including any associated data, should be done in a way that promotes reproducibility and therefore cost-efficiency and ultimately environmental protection. Shared FAIR data (Findable, Accessible, Interoperable, Reusable) will maximise their use and reuse, even if under specific user licence (Wilkinson *et al.*, 2016). And reproducible research, using tools such as `rmarkdown`[11], promote good practices (Alston & Rick, 2021), which will be required to ensure Environmental Impact Assessments indeed protect the natural environment that they are designed to.

3.3. Examples of strategic monitoring and management programmes

Following the workshops discussed in Sections 1 & 2, examples of what attendees deemed to be strategic approaches to monitoring and management were identified. A literature review by the authors of strategic (monitoring and management) approaches, added to a selection of potential strategic approaches to review in the context of the principles. The approaches were reviewed on the basis that they appeared to fit with *some* (if not all) of the principles in Section 3.2 (where they did not, this is explained) and cover different spatial scales, frequencies of monitoring and assessment, and have the potential to be widely applicable, i.e., to answer other questions. Note that this review of approaches is not systematic and therefore will not be comprehensive, but rather selected to give an indication of what works for strategic monitoring, and what should be avoided.

Note additional projects that were highlighted by stakeholders as having relevance for linking strategic monitoring to policy priorities are summarised in Appendix VIII.

3.3.1. UNECE Environmental Monitoring and Assessment Programme

The United Nations Economic Commission for Europe (UNECE) Environmental Monitoring and Assessment Programme aims to facilitate monitoring and assessment of environmental change to ensure the state of the environment meets national and regional policies, such as the UNECE Convention on Long-range Transboundary Air Pollution[12]. This programme sees member states across Eastern Europe, the Caucasus and Central Asia and interested countries of South-Eastern Europe, working collaboratively to promote the timely integration of relevant environmental data to support regional decision-making. The programme includes a Working Group on Environmental Monitoring and Assessment, in April of 2022, and Joint Task Force on Environmental Statistics and Indicators, held in October of 2021. Among the core tasks of the Working Group is to develop a Shared Environmental

[11] https://bookdown.org/yihui/rmarkdown/
[12] https://unece.org/node/22

Information System to which the member and interested countries can contribute and query to better characterise environmental changes at the regional scale. They also, however, support and assist with national environmental monitoring programmes, including sourcing necessary financing. The Joint Task Force publishes a list of over 40 environmental indicators covering issues from air pollution and biodiversity loss to agriculture and transport.

Summary
Web: https://unece.org/environment-policy/environmental-monitoring-and-assessment
- **Policy-driven** Yes, established to meet national and regional environmental policies. - **Collaborative** Yes, brings together international states to support data integration and regional decision making. - **Spatially and temporally resolved** Yes, covers 24 sessions and is worldwide. - **Adaptive with feedback** Yes, through the work Task Forces and Working Groups.

3.3.2. OSPAR North-East Atlantic Environment Strategy 2030

The Oslo Paris (OSPAR) North-East Atlantic Environment Strategy 2030 is an agreed strategy by which the 16 OSPAR contracting parties, including the UK, the European Union and several of its constituent countries, will implement objectives to tackle biodiversity loss, marine litter, and climate change in the North-East Atlantic (known collectively as the OSPAR convention). This contributes to achieving the United Nations 2030 Agenda for Sustainable Development and its Sustainable Development Goals. The strategy is based around four themes related to the impacts of human activities and is guided by strategic objectives relating to specific anthropogenic-derived stressors, including eutrophication, biodiversity and habitat loss, and underwater noise, each with its own operational objectives against which to assess progress.

The Thematic Assessment working groups under OSPAR use the Drivers-Activities-Pressures-State-Impact-Response (DAPSIR) framework (Figure 4) to assess progress under each objective and facilitates collaborative working through a standardised approach to improve all aspects of the assessment.

It is noted that data from localised monitoring are pieced together to provide an assessment for each assessment OSPAR region. Whilst the data collection is very limited and not primarily driven by this policy need, the spatial and temporal scale of the data are in many areas insufficient to confidently assess status and cause of trends. However, it is an example of bringing together data to help inform assessments of quality status, even whilst acknowledging the limitations of the data and assessments in managing the marine activities. In the context of the definition and principles of strategic monitoring some are met others are limited.

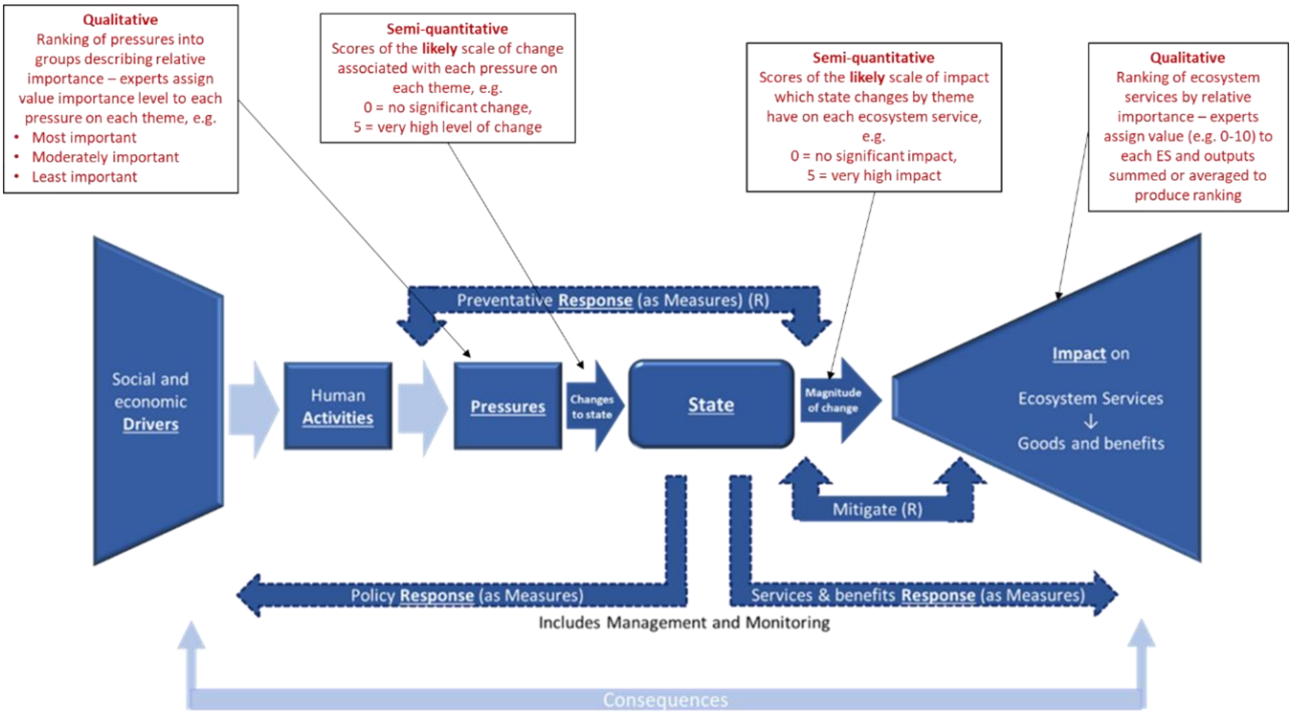

Figure 4 A schematic showing the DAPSIR assessment framework, together with summaries of discussions about it at the February 2022 joint Intersessional Correspondence Group for Economic & Social Analysis and Intersessional Correspondence Group for Cumulative Effects workshop on DAPSIR. Source: https://www.ospar.org/news/ospar-special-session-on-the-dapsir-framework

Summary
Web: https://www.ospar.org/convention/strategy

- **Policy-driven** Yes, overall**,** for protection of the North-East Atlantic but sub-policies also.
- **Collaborative** Partially, there are several working groups and committees that work across themes.
- **Spatially and temporally resolved** Yes to a degree, depending on the indicators being monitored by countries, and also temporally, data depends on the indicators. It is noted that the data limitations limit the application of the indicators due to low confidence
- **Adaptive with feedback** Yes, via the working groups and committees.

3.3.3. Long-Term Ecological Research network

The Long-Term Ecological Research (LTER) network connects national terrestrial, freshwater and marine ecological monitoring programmes and is guided by regional and international cooperation. It was started to address ecological challenges that might be best understood at large spatial and temporal scales, such as the effects of flood and drought events on forest die-back, and how they are changing under new anthropogenic stressors (Haase *et al.*, 2016). Through international cooperation, several resources have been realised to promote effective research, including the development and adoption of a metadata documentation system, a research tool catalogue, and even a thesaurus to ensure consistent language. There are over 600 sites in the network, which allows for broad spatial and temporal coverage that is difficult to achieve through synthesis of spatially and temporally misaligned individual studies. Such long-term, and widespread coordinated programmes make substantial contributions to our understanding ecological change, as is showcased in special issues of peer-reviewed scientific journals, including Ecological Indicators[13] and Science of the Total Environment[14].

Summary
Web: https://lternet.edu/; https://www.lter-europe.net/; https://www.ilter.network/
- **Policy-driven** Partially, primarily established to coordinate ecological research efforts, but increasingly used to assess national and regional environmental policies - **Collaborative** Yes, collaboration between national programmes is coordinated internationally to support data integration, tools, and communication - **Spatially and temporally resolved** Yes, covers over 800 sites and thousands of researchers worldwide - **Adaptive with feedback** Yes, through international coordination

3.3.4. UK Marine Strategy

The UK Marine Strategy Regulations 2010, which implement the EU Marine Strategy Framework Directive (MSFD), sets a statutory duty on the Secretary of State to take measures necessary to achieve or maintain Good Environmental Status (GES) of UK seas by 31 December 2020, primarily through the development of a UK Marine Strategy (UKMS). For a marine water to achieve GES, it should be ecologically diverse to promote resilience, clean, healthy, and productive within its intrinsic condition, and used sustainably, thus

[13] https://www.sciencedirect.com/journal/ecological-indicators/vol/65/suppl/C
[14] https://www.sciencedirect.com/journal/science-of-the-total-environment/special-issue/10WFPXL9F2S

safeguarding it for future generations The UKMS classifies the marine environment into 15 ecosystem descriptors[15] from cetaceans, through to benthic habitats, seafood contaminants and anthropogenic sound, to name a few. The high level ‘duty target’ to achieve or maintain GES for UK seas is an aggregation of 42 individual targets set under these 15 descriptors. The 42 targets are assessed by a suite of approximately 60 indicators every 6 years, including beach litter, abundance of key species, and the maximum sustainable yield for commercial fish stocks (several of these indicators are also used as indicators for the 25-Year Environment Plan). At last assessment in 2019, 6 of the 15 descriptors had not achieved GES (red), 5 had partially achieved GES (amber) and 4 had achieved GES (green). The reasons that some indicators did not achieve GES included insufficient measures in place, a slow response to measures, unachievable indicator design and insufficient data.

It is noted that data from localised monitoring are pieced together to provide an assessment. Whilst the data collection is very limited and not primarily driven by this policy need, the spatial and temporal scale of the data are in many areas insufficient to confidently assess status and cause of trends. However, it is an example of bringing together data to help inform assessments of quality status, even whilst acknowledging the limitations of the data and assessments in managing the marine activities.

Amendments and developments of the UKMS will be founded on principles of collaboration and efficiency by ensuring that it complements work to implement the OSPAR North-East Atlantic Environment Strategy 2030, the marine target for the Environment Act 2021 and the ecosystem objectives under the Fisheries Act, and that they dovetail with any targets set in the reviewed 25-Year Environment Plan (early 2023).

Summary
Web: https://www.gov.uk/government/publications/marine-strategy-part-one-uk-updated-assessment-and-good-environmental-status
- **Policy-driven** Yes, the UKMS supports policies such as the 25 Year Environment Plan. - **Collaborative** Partially, via OSPAR working groups and committees as well as across Devolved Administrations for the UK who collaborate on the collation and interpretation of the data to assess and provide conclusions. - **Spatially and temporally resolved** Somewhat, depending on the indicators being monitored by countries, and also temporally data depends on the indicators. It is

[15] cetaceans; seals; birds; fish; pelagic habitats; benthic habitats; non-indigenous species; commercial fish; food webs; eutrophication; changes in hydrographical conditions; contaminants; contaminants in seafood; litter, and; input of anthropogenic sound

noted that the data limitations limit the application of the indicators due to low confidence
- **Adaptive with feedback** Yes, during the six yearly review.

3.3.5. Environment Strategy for Scotland

The Environment Strategy for Scotland[16] is a framework designed to deliver national ambitions and meet national policies on nature, climate, resource use, economy, society, and global citizenship. It builds on the idea of three pillars of sustainability that promotes integration of social, economic, and environmental systems (Purvis *et al.*, 2019). To maximise the probability of achieving these ambitions, a range of monitoring framework indicators are used. The status and trends of indicators will be reported on an online platform which will be updated continually, as new data becomes available. Data will be accompanied by a narrative explaining what indicators infer about progress towards each outcome. The framework explicitly recognises that to be successful will require collaborative working between sectors and with other nations. As such, it will contribute to existing national policies, such as the Biodiversity Strategy and River Basin Management Plans, and international agreements, such as the Paris Climate Agreement.

The indicators cover a range of variables, such as biodiversity, pollutant and greenhouse gas emissions, water quality, litter, carbon footprint and natural capital accounting with reporting varying from annually to every six years.

Summary

Web: https://www.gov.scot/publications/environment-strategy-scotland-vision-outcomes/

- **Policy-driven** Yes, it aims to provide an overarching framework for Scotland's environmental strategies and plans.
- **Collaborative** Somewhat, it will be undertaken across Scottish agencies on a national level.
- **Spatially and temporally resolved** Once implemented, this should provide spatial and temporal resolution.
- **Adaptive with feedback** Yes, via the reporting and assessment periods.

3.3.6. WinMon.BE

Belgium is a world-leader in the consideration of the environmental impacts of offshore windfarm development as exemplified by the WinMon.BE integrated, stakeholder focused,

[16] https://www.gov.scot/publications/environment-strategy-scotland-vision-outcomes/

strategic programme of monitoring. Offshore wind energy is planned to contribute up to 20% of Belgium's total electricity demand by 2026. Belgium has a Marine Spatial Plan which sets out how they plan to develop offshore wind within their territorial waters to meet their ambitions. The WinMon.BE project started in 2008 and is a collaboration between the Royal Belgian Institute of Natural Sciences, the Research Institute for Nature and Forest, the Research Institute for Agriculture, Fisheries and Food and the Marine Biology Research Group of Ghent University. It was set up to monitor the impacts of Belgium's growing offshore windfarm developments, using an integrated monitoring programme that is unconstrained by geopolitical boundaries, and provides recommendations to optimise future monitoring efforts (Lindeboom *et al.*, 2015). The collaboration enables the key questions of stakeholders to be determined and then these are turned into operational research questions though an iterative dialogue, leading to a strategic series of targeted projects aimed at meeting the original key questions (see Gill *et al.*, 2020a). The WinMon.BE project progress is reported in annual updates published on the Operational Directorate Natural Environment website[17], and provide evidence for several important findings, for example a potential positive 'reef effect' at turbine foundations, or determination of large differences in the potential impacts of turbines on closely related species, such as common guillemots and great cormorants. Most importantly, the project has led to the conviction that offshore windfarm developments and spatial planning for nature protection can both benefit from careful and coordinated planning[18].

Summary
Web: https://odnature.naturalsciences.be/mumm/en/windfarms/
- **Policy-driven** Yes, to support the Belgian Marine Spatial Plans and supporting ambitions - **Collaborative** Yes, an integrated approach bringing together government agencies, industry operators and several academic institutions and University research groups. It also incorporates stakeholder consultations to define strategically important research questions. - **Spatially and temporally resolved** Within Belgian waters and provides annual data. Data are collected at turbine and also wind farm scale and modelled for national waters. - **Adaptive with feedback** Yes, through publicly available annual reporting since 2009 and review by programme steering group.

[17] https://odnature.naturalsciences.be/mumm/en/windfarms/
[18] https://www.belgianoffshoreplatform.be/app/uploads/OffshoreWindpark-eng-vFINAL_24062021.pdf

3.3.7. US National Aquatic Resource Surveys

The National Aquatic Resource Surveys (NARS) are collaborative programmes between the US Environment Protection Agency, States, and Tribes designed to assess the quality of the nation's waterbodies, from coastal waters to rivers, streams, and wetlands. It is founded on the historical Environmental Monitoring and Assessment Program (EMAP; McDonald *et al.*, 2002) that aimed to advance the science of ecological monitoring and ecological risk assessment through robust statistical sampling design. Due to its foundation on EMAP, NARS prescribes random stratified sampling site selection (by ecoregion, habitat type and waterbody), with flexibility to allow better representation of “sub-populations” while waiting for the additional representation. Many design aspects of EMAP were subject to active research in areas of variability and reference conditions, some of which would become legally adopted bio-criteria. EMAP also established a network of index sites, which are a smaller number of intensively monitored sites, often shared with collaborators, in which detailed research can reveal additional detail on temporal and episodic events. EMAP, and subsequently NARS, also facilitates information management and transfer to ensure important deliverables are made available as soon as possible.

Summary
Web: https://www.epa.gov/national-aquatic-resource-surveys
- **Policy-driven** Yes, to support water quality policies and targets. - **Collaborative** Yes, between the US Environment Protection Agency, states, and tribes. - **Spatially and temporally resolved** Unknown. - **Adaptive with feedback** Unknown.

3.3.8. US Magnuson-Stevens Fisheries Conservation and Management Act

The Magnuson-Stevens Fisheries Conservation and Management Act (MSA) is a law passed in 1976 to promote the long-term sustainability of marine fisheries in US federal waters[19]. As part of its enactment, 8 regional fisheries councils were established, each tasked with developing fisheries management plans that comply with the MSA, which must incorporate a set of national standards. Within its jurisdiction, each council must ensure that their important fish stocks are not overexploited and act where there is a risk or known case of overexploitation. To assess these risks and cases, the councils appoint councillors with specific scientific and statistical expertise, including private citizens, state officials from

[19] https://www.fisheries.noaa.gov/topic/laws-policies

relevant areas and administrators. The councillors contribute to committees that include additional experts. For example, the Mid-Atlantic Fisheries Management Council has several species-specific committees whose members are regional experts for those species, and functional committees, spanning topics from Law enforcement to Scientific and Statistical[20]. Through this structure, the MSA ensures a large spatial and temporal monitoring programme to protect important fish stocks for healthy future ecological and economic systems.

Summary
Web: https://www.fisheries.noaa.gov/resource/document/magnuson-stevens-fishery-conservation-and-management-act
- **Policy-driven** Yes, enacts national and regional laws to protect fish and fisheries. - **Collaborative** Yes, collaboration between regions and increasingly internationally. - **Spatially and temporally resolved** Yes, covers all US federal marine waters since 1976. - **Adaptive with feedback** Yes, through expert committees and stakeholders.

3.3.9. UK Marine Protected Areas

Marine protected areas are parts of the sea identified as important for the protection of marine habitats and species. It is noted that the monitoring is generally site specific and there is little to no coordination between those responsible and on a national level due to lack of funding. However, the combined these MPAs are used to meet national targets on percentage of seas under protection (e.g. 30% by 2030).

In the UK, the Joint Nature Conservation Committee (JNCC) provides scientific advice to UK government and devolved administrations on designating and monitoring of MPAs by (i) working together with other parts of the UK government and the country Statutory Nature Conservation Bodies (SNCBs) with responsibility for monitoring MPAs in inshore waters (< 12 nautical miles [nm] from the coast), and (ii) monitoring offshore MPAs (from 12 nm from the coast out to the limits of the UK continental shelf). JNCC scientific advice has included reviews of international MPA monitoring (Addison, 2011; Parry *et al.*, 2012), a review of monitoring and assessment in UK inshore MPAs by the SNCBs using Common Standards Monitoring between 1999 and 2013 (McBreen *et al.*, 2016), and guidance for robust monitoring of benthic habitats (Noble-James *et al.*, 2018). JNCC leads on operational monitoring of MPAs in UK offshore waters to assess their condition, report on whether they are meeting their Conservation Objectives, and produce advice on their management. The

[20] https://www.mafmc.org/committees

JNCC collect robust and standardised monitoring data to assess long-term trends, specific pressure-state relationships, and to fill knowledge gaps[21].

Within 12 nm of the coast, monitoring of inshore MPAs is the responsibility of the country nature conservation bodies of the devolved administrations as follows (note that these are disparate monitoring programmes):

3.3.9.1. Scotland

Marine Scotland (MS) and Marine Scotland Science (MSS), in partnership with NatureScot and JNCC has developed The Scottish MPA monitoring strategy covering the Scottish waters MPAs[22][23]. The strategy is an approach to MPA-related survey and monitoring and is supported by a series of annexes that provide more detail on monitoring methods, collaborative working, current monitoring and a two year forward look for MPA monitoring in Scottish waters.

The strategy provides:

- direction for monitoring, assessment, and reporting on the MPA network;
- guidance on standardisation of monitoring objectives, sampling design, and methodologies;
- principles for prioritising MPA-related monitoring;
- consideration of using proxy methods (e.g. pressure information) to meet requirements; and,
- recognition of the importance of collaborative and citizen-led science programmes.

The Strategy is a working document which will be reviewed on a regular basis in collaboration with partner organisations. The purpose of the strategy is to develop a long-term approach to MPA-related survey and monitoring effort.

3.3.9.2. Wales

The Welsh government has developed an MPA Network Framework for Wales 2018 – 2020[24]. This framework sets out how to manage, monitor and improve inshore MPAs and is accompanied by an annual action plan detailing the actions identified to improve

[21] https://data.jncc.gov.uk/data/b15a8f81-40df-4a23-93d4-662c44d55598/Marine-Monitoring-Strategy-v4.1.pdf
[22] https://www.gov.scot/policies/marine-environment/marine-protected-areas/
[23] https://www.webarchive.org.uk/wayback/archive/20180528130830/http:/www.gov.scot/Topics/marine/marine-environment/mpanetwork/MPAmonitoring
[24] http://www.assembly.wales/laid%20documents/cr-ld12871/cr-ld12871%20-e.pdf

management and conditions of MPAs[25]. Natural Resources Wales is responsible for gathering evidence and providing advice of the condition of inshore MPAs.

In 2018, the best available data for appropriate indicators were used to assess the status of several MPAs. An ongoing project aims to develop an approach to undertaking regular and improved assessment of those MPAs by assessing alternative indicators, what and how they are measured and trialling alternative assessment methods[26].

3.3.9.3. England

Natural England advises on inshore MPAs (Liley *et al.*, 2012; MarineSpace Limited, 2019). Between 6 and 12 nm from the coast, the Marine Management Organisation (MMO) oversees management to ensure fishing is compatible with the conservation objective of the MPAs. Within 6 nm from the coast, this responsibility falls under the Inshore Fisheries and Conservation Associations (IFCAs). Natural England also undertakes MPA monitoring, condition assessment, baseline monitoring and provides conservation objectives and supplementary advice. Furthermore, Natural England have delegated responsibilities for advising on offshore works from the JNCC, such as all offshore windfarms. It should be noted that Natural England and JNCC collaborate frequently on monitoring MPAs in English waters[27].

The UK has also implemented the integrated Marine Biodiversity Monitoring Scheme, which is a long-term project to improve and better-focus monitoring, conducted in multiple stages. The results of the monitoring activities are used to redefine expectations in the functions of the Scheme. The Scheme has been set up with the specific objective of developing options that can be proposed to the UK Government for an integrated monitoring and assessment scheme for marine biodiversity components. In the first instance the focus will be on the design of monitoring options for the components, cetaceans, seals, seabirds, fish & cephalopods, benthic habitats and ecosystem processes and functions. Monitoring in MPAs is included for each ecological component[28].

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[25] https://gov.wales/sites/default/files/publications/2021-09/marine-protected-area-network-management-action-plan-2021-2022.pdf
[26] https://naturalresources.wales/guidance-and-advice/environmental-topics/wildlife-and-biodiversity/protected-areas-of-land-and-seas/indicative-feature-condition-assessments-for-european-marine-sites-ems/?lang=en
[27] http://publications.naturalengland.org.uk/category/6314156996165632
[28] https://data.jncc.gov.uk/data/b15a8f81-40df-4a23-93d4-662c44d55598/Marine-Monitoring-Strategy-v4.1.pdf

3.3.9.4. Northern Ireland

The Department of Agriculture, Environment and Rural Affairs (DAERA) commissioned JNCC to assess inshore MPAs around North Ireland[29] against their Charting Progress 2 marine conservation policy commitments (UKMMAS, 2010). The assessment identified geological/geomorphological features, habitats and species currently protected by inshore MPAs and compared them to an agreed set of criteria that define an ecologically coherent network to measure their conservation value and any gaps in their coverage (Chaniotis *et al.*, 2018).

3.3.9.5. Scottish, Irish, and Northern Irish collaboration

Agri-Food and Biosciences Institute in Northern Ireland, together with Marine Scotland, Scottish Natural Heritage, University College Cork, Ulster University, Scottish Association for Marine Science and BirdWatch Ireland, set up MarPAMM[30] – an environment project to develop managing and monitoring tools to improve the effectiveness of MPAs. MarPAMM works closely together with two other projects in the region COMPASS and SeaMonitor. The project was completed on 31 March 2022. The project aimed at collecting data on the movement, distribution and abundance of habitats and marine protected species. It will produce a regional sea bird model, a seal foraging model, underwater noise model, a regional model of protected seabed-dwelling species and a coastal process model. The project contributed to the development of six MPA management plans. Data from this project can feed into the strategic monitoring of MPAs.

Summary
Web: https://jncc.gov.uk/our-work/about-marine-protected-areas/
- **Policy-driven** Yes, to meet policies such as 25 Year Environment Plan and 30% by 2030. - **Collaborative** Limited. The monitoring programmes are disparate between Devolved Authorities and SNCBs. - **Spatially and temporally resolved** To a degree, depends on the feature being monitored and Devolved Administration. - **Adaptive with feedback** Limited, mainly focussed on conservation objectives.

29 https://www.daera-ni.gov.uk/publications/assessing-progress-towards-ecologically-coherent-network-marine-protected-areas-northern-ireland#:~:text=Following%20the%20designation%20of%20four%20Marine%20Conservation%20Zones,network%20against%20Northern%20Ireland%E2%80%99s%20marine%20conservation%20policy%20commitments.

30 https://www.mpa-management.eu/

3.3.10. UK Water Quality Monitoring

The UK Environment Agency monitors water quality of coastal or estuarine waters, rivers, lakes, ponds, canals or groundwaters across England (and until 2013, across Wales). Water samples are taken for several purposes, including assessing compliance against discharge permits, investigating pollution incidents and environmental monitoring. For example, water samples can be analysed for pollutants, including hydrocarbons, metals, physical properties, including dissolved oxygen and temperature, and biological properties, including phytoplankton. Monitoring and reporting are designed to meet the requirements of the Water Framework Directive (England and Wales) Regulations 2017 (implementing the EU Wafter Framework Directive) and is conducted in waterbodies grouped to support a regional approach to monitoring and assessment. These groupings are designed to account for temporal and spatial variability of waterbodies due to sampling considerations, such as number of sites and frequency of monitoring, or other sources of variability, such as seasonal trends.

Applications that could affect water quality, e.g., dredging projects, are required to undertake an assessment to determine the potential impacts their project can have on water quality. Some of the monitoring can be used to inform strategic monitoring if the determinands (pollutants or chemicals) of concern have/are being measured.

Summary
Web: https://www.gov.uk/government/organisations/environment-agency/
- **Policy-driven** Monitoring designed to comply with Water Framework Directive (England and Wales) Regulations 2017 - **Collaborative** Predominantly undertaken by Environment Agency. - **Spatially and temporally resolved** Monitoring is done nationally and waterbodies are grouped to account for common sources of variability - **Adaptive with feedback** Limited.

3.3.11. Disposal site monitoring

Disposal of waste at sea is strictly regulated through the licensing requirements of the Marine and Coastal Access Act 2009 (MCAA). The MCAA provides the principal statutory means by which the UK complies with EU law, such as the Water Framework Directive (WFD, 2000/60/EC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC) and international obligations such as under the OSPAR Convention and the London Protocol, in relation to disposals at sea.

The MMO regulates, and is responsible for, licensing activities in the marine area around England including the disposal of dredged material at sea. The MMO assesses the suitability of dredged material for disposal at sea in line with the OSPAR Guidelines for the management of dredged material (OSPAR Commission, 2014). These guidelines provide generic guidance on determining the conditions under which dredged material may (or may not) be deposited at sea and involve the consideration of alternative uses, disposal sites and the suitability of the dredged material for aquatic disposal including the presence and levels of contaminants in the material, along with perceived impacts on any nearby sites of conservation value.

Monitoring of disposal sites is required where there is a high level of risk or uncertainty as such monitoring is carried out by the applicant to reduce uncertainty, assess potential impacts (are they as expected?) or to validate the findings of the assessment. As this monitoring is carried out by the applicant to answer a specific question, monitoring is often for specific variables (e.g., certain chemicals, bathymetry) and vary considerably between sites, and are for a limited time period. For those sites that are for beneficial use, such as ecological restoration, monitoring may be required to ensure the sites meet the environmental benefits as predicted in the assessment. These beneficial use sites are important for ecological restoration projects as they help to support policies such as the 25 Year Environment Plan or Green Paper which aim to increase biodiversity and restoration projects.

Additionally, the MMO and Cefas have an agreement whereby Cefas undertakes disposal monitoring on behalf of the MMO. Due to the large number of disposal sites, the MMO and Cefas prioritise sites using a tier-based approach that classifies several possible issues or environmental concerns that may be associated with dredged material disposal into a risk-based framework (Birchenough *et al.*, 2010; Bolam *et al.*, 2011). The issues that pertain to a particular disposal site, and where these lie within the tiering system (i.e., their perceived environmental risk) depict where that site lies within the tiered system. This ultimately determines whether that site is considered for sampling during a particular year. It is intended that this approach increases the transparency of the decision-making process regarding disposal site selection for monitoring, i.e., it establishes a model for site-specific decisions regarding sampling.

Depending on the tier-based approach and the concerns raised, monitoring can include, but is not limited to chemical and physical analysis of sediments from the surface or depth, hydrodynamic modelling, and bathymetric surveys[31]. Irrespective of these site selection criteria, licence holders may be required to monitor disposal sites if they are a new disposal

[31] https://www.gov.uk/government/publications?departments%5B%5D=centre-for-environment-fisheries-and-aquaculture-science

site, if there has been a significant change to an existing disposal site, such as the type or volume of material deposited, or to measure the impact of any mitigation measures.

Summary
Web: https://www.gov.uk/guidance/marine-licensing-sediment-analysis-and-sample-plans
- **Policy-driven** For reporting requirements, it is driven by the London Protocol not policy, however, the policies to increase biodiversity are supported by the designation of beneficial use sites. - **Collaborative** Limited: Devolved Administrations submit returns to Cefas for the UK and is assessed by international Conventions. - **Spatially and temporally resolved** Temporally and spatially the data are limited. - **Adaptive with feedback** No.

3.4. Human impacts and monitoring themes

In this section, using the same criteria and method as described in Section 3.3 and building on the selection of programmes presented there, some additional selected and relevant environmental monitoring programmes designed to assess the impact of human activities around the UK and overseas are reviewed. The human impact activities and programmes to monitor them that were reviewed were chosen to highlight the range of approaches that are appropriate from a strategic perspective, their rationale, and methods used. In reviewing these, several monitoring themes were identified, and where possible the environmental monitoring programmes are discussed under those themes.

3.4.1. Fishing

Fishing is a major human activity for many nations, especially those with a large coastline such as the UK. For these countries, fishing constitutes an important contribution to the national economy. For example, the latest landings by UK fishing fleets were worth approximately £831 million[32]. Given the level of fishing activity and its importance to national economies, there is a clear need to understand the impact of fishing on the natural environment, including the fish stocks themselves.

[32] https://www.gov.uk/government/news/fishing-industry-in-2020-statistics-published

3.4.1.1. Fish

Fishing will impact the stocks of fishes being targeted, as well as those not being targeted (e.g., through by-catch or through disturbance). Understanding how different stocks are impacted requires data with which to estimate stock variability and positive and negative impacts. Fisheries data are often used for this purpose. Ware *et al.* (2021) undertook a review of the national monitoring that is undertaken for fisheries (fin fish and shellfish, including recreational fisheries and socio-economic monitoring). A summary is provided in Figure 3. This shows that there is already a comprehensive approach to data and evidence collection at a national scale and these data are fed into multinational committees and councils, such as the International Council for the Exploration of the Seas (ICES), to monitor, assess and manage our fisheries resources effectively and sustainably, and maintain UK scientific credibility at both the national and international level.

Such data come in many forms, including long-term fisheries-dependent time series of commercial landings data and single fisheries-independent scientific survey data. For monitoring at a broad spatial and temporal scale, it is important to consider commercial fisheries landings data, which can also entail engagement and buy in from the sector. Local fishing knowledge can also be used to highlight the important fishing grounds which need protection. However, using local fishing knowledge needs to be undertaken with care. Expert advice would still be needed regarding sampling strategy of regions and fishing vessels. Ensuring that the numbers of local fishers are adequate and provide a comprehensive image of the extent and type of fishing activities by fleet segments and communities along the coast (des Clers, 2010). Monitoring can focus on specific species of commercial importance, with a range of data sources available to describe the local regional fleets and their targeted species. These include fisheries-dependent commercial landings data from the MMO[33] and by ICES rectangle[34], which can also include the fisheries species targeted, gear type and size of vessel, onshore port and market sampling programmes, and offshore observer programmes. In combination, these different data types are considered to comprehensively cover the different catch components (e.g., landed catch, bycatch), different parts of the species populations (e.g., spatial distribution, catch at age) and can provide different catch indices. However, while these commercial landings data can be abundant and with broad spatial and temporal coverage, they are also limited to commercially important species and omit non-quota finfish and shellfish species and are subject to the biases introduced by the main reason for collecting the data – to catch fish, i.e., they are collected where fish are expected to be, rather than at random, and using gear that is designed to catch the fish rather than just taking an unbiased sample. They are also limited to vessels of a certain size.

[33] https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics
[34] https://www.ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx

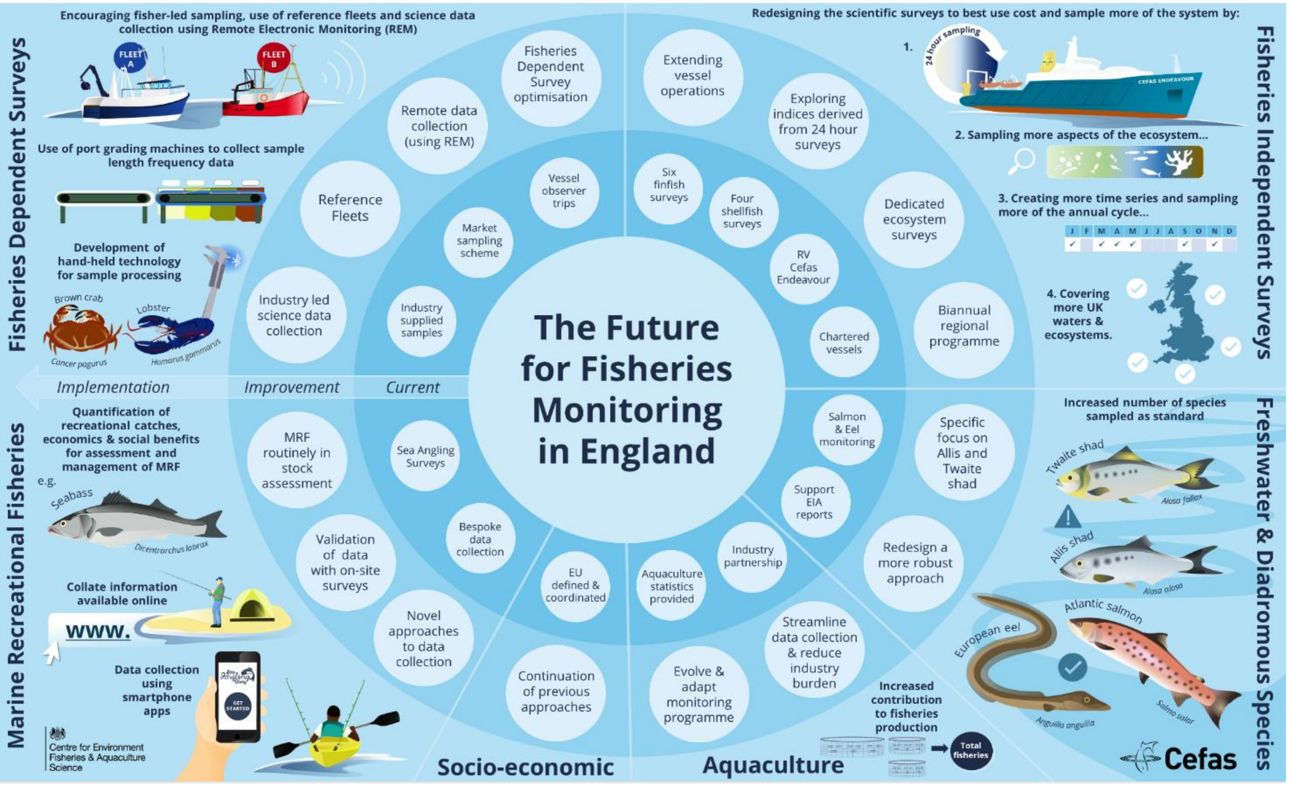

Figure 3 Summary of fisheries monitoring currently undertaken in the UK and the recommendations for improving monitoring/data.

Fisheries-independent data are derived by scientific surveys and are often collected alongside or in addition to the fisheries-dependent data. The data generated by fisheries-independent surveys are generally collected using dedicated research vessels, with some contribution from commercial vessels commissioned specifically for scientific monitoring data collection. Trawler gears and/or imagery methods are used to obtain semi quantitative data on catch composition with further processing of the catch samples providing biological information. There are currently 25 UK fisheries-independent surveys conducted annually, including several by Cefas such as the six finfish surveys (Research Vessel Endeavour), the Western Channel survey (commercial vessel), the four shellfish spp. surveys, and the Cefas Young Fish Survey (YFS) from 1981-2019. Many of these data are available for stock assessment. For example, the Cefas data are available through the Cefas data portal[35] and the archive centre[36]. These data could be particularly useful for cases where international surveys do not currently survey (i.e., inshore waters). For instance, Cefas collects herring samples from the greater Thames area and southern North Sea[37], which provides some limited data on biological maturity and age data for the Thames / Blackwater herring stock, as well as stock allocation. These data may also provide complementary data on herring spawning times for the Downs and Thames sub-stocks.

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[35] https://data.cefas.co.uk/
[36] https://www.cefas.co.uk/data-and-publications/fishdac/
[37] https://data.cefas.co.uk/view/5

Another notable source of fisheries-independent survey data are those data collected by the International Council for the Exploration of the Seas (ICES), which include a comprehensive library of data[38] to support information gathering that can be filtered by species and by area. There are also ICES Working Groups, such as the ICES Working Group for North Atlantic Salmon (WGNAS) and the International Bottom Trawl Survey (IBTS), that collate data for stock assessments of specific species or regions. Often, these working groups undertake detailed stock assessments for specific species, such as Atlantic salmon by WGNAS[39], and increasingly within an ecosystem-based approach (Bull *et al.*, 2022), such as WKSalmon[40]. Although these data are also subject to some biases due, for example, by gear selectivity, the degree of bias can be less than for fisheries-dependent data, depending on the sample collection protocol. Given the cost of collecting these data, however, and their lack of commercial value, they tend to be far less common than the more abundance fisheries-dependent data.

3.4.1.2. Benthic ecology

Trawling is a common fishing method, whether otter or beam trawls or towed or hydraulic dredges. Many studies have demonstrated that they can be destructive to physical processes and the benthic ecology at individual sites, but more recent meta-analyses have extended these findings to larger regions of the seabed internationally. For example, Hiddink *et al.* (2017) and, more recently, Pitcher *et al.* (2022), have both shown that destruction from trawling is widespread and negatively impacts benthic communities and habitats, sometimes with effects lasting several years.

There are several programmes aimed at mapping seabed habitats, which can be related to specific fish species or benthic communities. For example, the One Benthic Sediment Change Tool[41] can help monitor changes to seabed habitat that might affect specific fish species by, for example, damaging their spawning habitat. The EMODnet seabed mapping tool aggregates and simplifies querying of European-wide seabed habitat survey data, including modelled data layers of habitats and sediments[42]. Similar tools with varying data content are available for different nations, such as MAREANO[43] for the Norwegian sea, and can be queried to better understand the impacts of trawling on seabed processes, including marine litter (e.g., Buhl-Mortensen & Buhl-Mortensen, 2018). Although they are resource intensive to set up, these tools are useful in collating large datasets as they can provide a national picture of the benthic habitats, taxon assemblage distribution and ecological function including if the changes observed as likely due to natural variation (and no intervention required) or human activities (consider if further action is required).

[38] https://www.ices.dk/advice/Pages/Latest-Advice.aspx and https://www.ices.dk/data/dataset-collections/Pages/default.aspx
[39] https://www.ices.dk/community/groups/pages/wgnas.aspx
[40] https://nasco.int/wp-content/uploads/2020/08/ICES-wksalmon_2019.pdf
[41] https://rconnect.cefas.co.uk/onebenthic_sedimentchange
[42] https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/
[43] https://www.mareano.no/en

Furthermore, they help attribute changes to anthropogenic activities or natural variability on a regional basis (with reference stations outside zones of influenced included in the statistical design).

3.4.1.3. Seabirds

A recent assessment using the IUCN Red List and a survey of the online databases and primary and secondary literature found that bycatch from commercial fishing was among the three most negative and widespread threats to seabird populations globally (Dias *et al.*, 2019). Although the number of species affected as bycatch were fewer than the number affected by invasive alien species (such as black rats *Rattus* and domestic mice *Mus musculus)*, several bycatch species were impacted strongly. Data to support these studies tend to come from onboard observer programmes that are often reported separately. The Bycatch Management Information System[44] keeps a bibliography of these studies, among studies of bycatch of other taxa, including marine mammals and turtles, and reviews of such studies have been synthesised to gain a broader perspective of the effects of fisheries on seabirds, such as (Kuepfer *et al.*, 2022). For larger and more perceived sensitive species, other data are collected, including tracking data, and much of this data is held centrally in Birdlife International's Seabird Tracking Database[45]. Efforts to understand the interactions between fisheries and seabirds have led to specific recommendations to minimise any negative interactions (Le Bot *et al.*, 2018). Thus, whilst data are collected and often stored, there is no standardisation, even though impacts are noted in the literature and are often reported comprehensively.

3.4.1.4. Marine mammals

Interactions between fisheries and marine mammals are attributed to two simple ideas: (1) fisheries take food away from marine mammals such that the two compete for fish either directly by depredation or indirectly by longer-term depletion of fish stocks, and (2) fisheries can directly harm marine mammals, particularly through bycatch (Jog *et al.*, 2022). Increasingly, there is acknowledgement that these interactions need to be accounted for in our understanding of the impacts of fisheries on the natural environment, such as accounting for depredation rates in fish stock estimates (e.g., Earl *et al.*, 2021). Our growing understanding and recognition of interactions between fisheries and marine mammals has fostered a wave of resources to aid in their consideration when planning monitoring programmes. For example, the US Marine Mammal Commission[46] coordinates abundant resources on marine mammal topics, including effects of climate change, offshore energy developments, and their health and strandings.

[44] https://www.bmis-bycatch.org/index.php/
[45] http://www.seabirdtracking.org/
[46] https://www.mmc.gov/

Around the UK, the University of St Andrews Sea Mammal Research Unit[47] is the leading expert in similar topics and provides important resources for understand the distribution and abundance of marine mammals around UK coastlines, such as the At-Sea Density Maps for Grey and Harbour Seals in the British Isles (2020)[48]. While these data encompass a broad spatial and temporal scale, they are somewhat limited in quantity. The At-Sea density maps for Grey and Harbour seals and made from 270 grey seals tagged between 1991 and 2016 and 330 harbour seals tagged between 2001 and 2016, which constitutes only a small proportion of the population monitored intensively. These tag data are, however, supplemented with grey and harbour seal-haul out count data from 1996 to 2015, which are subject to common caveats such as double-counting and species misidentification. Although not an explicit feature of the data, they could be used to inform interactions between seals and fisheries.

In the UK, harbour porpoise bycatch is monitored by ICES, who estimate the numbers of harbour porpoises caught in commercial nets (mainly gillnets) in the ICES derived Assessments Units. The bycatch estimates are derived from the estimates of annual fishing effort and the count of harbour porpoise bycatch made by observers or remote electronic monitoring on commercial fishing vessels. Data are collected primarily through an observer scheme that should operate for specific fishery types. However, the coverage of gillnet fisheries, for example, is generally low for multiple reasons. Under EC Council Regulation 812/2004, monitoring is mandatory for vessels over 15 m, with pilot studies and scientific studies are required for vessels under 15 m. Most of the gillnet vessels are smaller than 15 m, plus fleet sizes for gillnet fisheries can be large for different countries[49]. The monitoring is also limited to only commercial fisheries, while also recreational netting takes place and goes unmonitored resulting in bycatch estimates with unquantifiable biases and wide confidence intervals, diminishing the confidence of reported impacts on population size. Other organisations are also resolved to monitor and mitigate against cetacean bycatch, including ASCOBANS[50].

3.4.1.5. Other considerations

Both commercial fishing and human activities span geopolitical boundaries at different points in space and time. Any strategic monitoring programme will need to account for this fact. There is a real need to understand and account for the activities of other nations and stakeholders, such as Devolved Administrations and others working within Exclusive Economic Zone (EEZ) shared seas. To help with this, routine surveys, such as fisheries-independent stock monitoring assessments should be considered, and consistent and comparable methods need to be agreed, which would facilitate development of a regional

47 http://www.smru.st-andrews.ac.uk/
48 https://doi.org/10.17630/dcebb865-3177-4498-ac9d-13a0f10b74e1
49 https://www.ices.dk/community/groups/Pages/WGBYC.aspx
50 https://www.ascobans.org/

approach to monitoring, rather than just trying to piece together an overview from individual assessments.

Any regional approach to monitoring should also consider the fishing industry, with regular engagement and involvement with commercial fisheries sector. This is important because fishing vessels of >12 m have a legal requirement to have a Vessel Monitoring System (VMS) installed, which monitors fishing activities. It shows where fishing vessels are and have been and an indication of how long they were in a specific area. However, the same requirement is not applied to vessels <12 m. Thus, to understand the important fishing grounds for certain species, including timings, engagement with the fishing industry is required who have this knowledge. Even with VMS there are limitations with regards to the resolution because the VMS only pings once every 2 hours so accounting effects to fishing is difficult.

Any approach to strategic monitoring, in this case focused on fisheries, should be built around data which are robust and integrated with existed approaches. Some monitoring might need to be species-specific, based on life history, stock unit sizes, biological range, and our current level of understanding of the species. In planning strategic monitoring of fisheries, the timing of surveys will need to consider important time periods (such as spawning) for the targeted species to be able to assess if changes that are happening are due to natural or anthropogenic reasons (Radinger *et al.*, 2019).

Summary

- **There are many fisheries related surveys undertaken depending on the rationale for the surveys e.g., stock assessment or recreational value that are both considered strategic monitoring in their own right but also the data can be used to inform future strategic monitoring programmes.**
- **Fisheries surveys requires considerations such as timing which will vary on the hypothesis, species, and location.**
- **Some limitations to data e.g., no VMS for <12 m fishing vessel fleet**
- **Whether data can be used or adapted for strategic monitoring programmes, will depend on the specific requirements to meet the strategic hypothesis.**

3.4.2. Offshore wind

Renewable energy, especially offshore wind (OSW)[51], is an area of substantial and increasingly fast growth in the UK and elsewhere in the world. For example, the UK government recently released the British Energy Security Strategy policy paper[52] outlining

[51] Although offshore wind is only one type of offshore renewable energy schemes, it is the most developed and only few examples of other schemes exist and are therefore not discussed.
[52] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

ambitions to quadruple offshore wind energy generation to 50GW by 2030. Given the expected growth in this area, it is important to consider the potential impacts of such developments on the natural environment.

In the UK, human marine activities are under the jurisdiction of the MMO for English, Natural Resources Wales for Welsh, DAERA for Northern Irish and Marine Scotland in Scottish waters.

Marine Scotland use Regional Locational Guidance (RLG) to facilitate the development of offshore wind energy in Scottish Waters. RLGs provide an overview of key strategic issues (environmental, technical, socioeconomic, and planning) in relation to the Scottish Marine Areas identified for renewable energy development. While they provide important datasets, RLGs are not set out to address any specific monitoring or strategic approach other than assisting in better marine planning. However, there are also Regional Advisory Groups (RAGs) whose remit is to provide advice on appropriate and effective monitoring to developers in support of their consent and licence requirements. An important element of the RAGs is their encouragement of developers to collaborate on their site monitoring activities within a region, which looks towards more strategic outputs based on the site monitoring.

Elsewhere in UK offshore waters, the MMO uses Marine Plans to provide protection and enhance our marine environment and support UK economic growth by enabling sustainable marine activities and development. The Marine Plans have a long-term view to meet their sustainable objectives and guide joined up and more integrated considerations of human activities in the offshore environment. All these aspects are fundamental to developing and supporting strategic approaches to monitoring.

Strategic monitoring for OSW (both existing and future developments) is vital in the context of the UK having a future sustainable marine environment and is needed to better understand the effects and impacts of this activity at the right scale. At present approaches to OSW monitoring occur at the project site level, however when considering cumulative effects, for example, and through groups such as the Scottish RAGs, there are some project-level actions that fit better with a strategic approach. For example, benthic monitoring used in the aggregate industry for English waters is done at a regional scale to understand better the significance of changes to benthic communities and whether these changes are likely due to the extraction of aggregates or due to natural variation at an ecologically relevant scale.

An example of an RAG that is implementing a strategic monitoring approach is the Forth & Tay RAG[53] that covers offshore wind farms in the Forth and Tay region. Under the conditions of the OSW consents, developments within the Forth and Tay must submit to the Scottish

[53] Forth & Tay Regional Advisory Group (FTRAG) | Marine Scotland Information

Ministers for approval an Environmental Management Plan and a Project Environment Monitoring Programme which have been developed, reviewed, and agreed through the FTRAG. FTRAG also encourages collaboration with developers monitoring programmes to provide more strategic outputs, they will review raw data and reports from the monitoring to provide advice to the Scottish Ministers. The monitoring requirements that are incorporated into the licence conditions are to:

- validate, or reduce uncertainty in predictions on environmental impacts recorded in supporting Environment Impact Assessments ("EIA") and Habitats Regulation Assessments ("HRA");
- provide evidence on the effectiveness of mitigation measures; and
- allow identification of any unforeseen consequences.

Work has already been undertaken for marine mammals and ornithological monitoring.

Post-consent monitoring of OSW projects provides outputs that can assist with identification of good practice), relevant output and knowledge gaps that may be relevant for strategic monitoring. For example, monitoring underwater noise during construction is assessed against a baseline that allows the effectiveness of mitigation measures or good practice to be assessed. Ecological and environmental monitoring data can contribute to a better understanding of the sources of natural variations, which in turn improves ability to isolate changes due to developments. In 2014, the MMO (2014) undertook a review of post consent monitoring on OSW developments with a view to updating their approach where required for developments in their jurisdiction. The findings of that review are pertinent to strategic monitoring of the future growth in UK offshore wind energy developments and are discussed below.

3.4.2.1. Physical processes

Wind turbines, just as with any rigid structure placed in a dynamic system such as a sea, will modify the physical processes around them, including scour, sediment movement, local hydrodynamics and even coastal morphology, ocean stratification and primary production (Dorrell *et al.* 2021). Of these processes, the one most common subject to required monitoring is the assessment of scour, usually using a 100% multibeam echosounder to characterise bathymetry. These surveys are carried out every 6 months for 3 years post-construction. In addition, there are also conditions to carry out the MBES surveys following a storm event, ranging from 1 in 10-year to 1 in 50-year events to ensure no additional scour has occurred due to the storm event. Occasionally, monitoring for suspended sediment concentrations is required to verify that possible negative impacts identified in an Environmental Impact Assessment (EIA), such as damage from jetting on a nearby sensitive feature, are not occurring. Currently the data generated from these surveys are not standardised and therefore are not comparable to be collected and used in a strategic monitoring programme. The data are also not always publicly available and therefore cannot be used in a strategic monitoring programme. Although data can be shared with the Maritime

Coastguard Agency under the Civil Hydrography Programme[54], which feeds into the UK Hydrographic Office ADMIRALTY Marine Data Portal. The comparability issue is more of a priority as if the data cannot be collated and compared, they cannot support strategic monitoring.

3.4.2.2. Benthic ecology

Benthic monitoring has been generally required for offshore wind developments, both within the array and along the export cable, and in reference areas that are deemed to be unaffected by the development. Monitoring techniques include benthic grabs, acoustic techniques and drop-down camera and video, beam trawling, intertidal surveys, and turbine colonisation studies to detect and quantify the native and non-native species. By comparing the results of monitoring data between areas possibly impacted by the development with areas deemed to be unaffected by the development, it is hypothesised that any non-negligible impact on the benthic community will be identified. However, in England, the MMO (2014) report found that flaws in survey design, longevity of monitoring, data analysis and interpretation in many of the cases reviewed, which could compromise any finding of no impact. Some of the flaws identified by the MMO (2014)[55] could be overcome by better standardisation and sharing of survey data, as has been demonstrated in the aggregate extraction sector (see below; Cooper, 2013).

3.4.2.3. Fish

There is currently limited data available to assess the population effects of installation and operation of offshore windfarms on fish species, with most wind farm monitoring focusing on the likely impact on specific species. The specific focus of monitoring will vary depending on the presence of protected or vulnerable fish species, such as herring *Clupeidae* spp., Atlantic salmon *Salmo salar*, or sandeel *Ammodytes* spp. All planned developments are required to present an Environmental Statement outlining the information reasonably required to assess the likely significant environmental effects of the development. In offshore windfarm development Environmental Statements, it is often highlighted that they act as a refuge or aggregate area for fish, although there is currently limited information available to support these assertions. There are also, however, possible negative impacts, including loss of spawning or feeding habitat, and disturbance to community interactions and migration routes, especially among anadromous species, such as Atlantic salmon (Gillson *et al.*, 2022). Annual variation in the abundance of fish populations can be considerable and coupled with the inefficiencies of the gear used to sample the populations, can render the measurement of any change in their abundance uninformative., This is especially true when the period of monitoring is short, as data of limited temporal (or spatial) scale result in constrained analysis and low statistical power and therefore difficulty in drawing meaningful

[54] https://www.gov.uk/guidance/share-hydrographic-data-with-maritime-and-coastguard-agency-mca
[55] It is noted that the MMO review was of all post consent monitoring carried out by 2014 and the approach has evolved to generally more hypothesis driven and targeted monitoring.

conclusions, if at all possible. Although offshore windfarm developers are required to provide monitoring data as part of their marine licence, these data are only available to those directly monitoring the impact of the windfarm and not available more broadly (Gill *et al.*, 2020a). Since variability in population abundances due to natural fluctuations and sampling efficiencies reduces with increasing abundance and numbers of surveys, making these data available to be used together for a wider spatial and temporal understanding of natural population changes could be a possible remedy for their individual shortcomings (Wilding *et al.*, 2017). This idea could extend beyond individual developers and industries.

Scour protection is often used around the base of wind turbines and to safely protect the integrity of cables, especially in areas with a high seabed mobility. This protection, often in the form of inert hard substrate, such as boulders, can act as an environment to encourage crustaceans and could present opportunities for co-location of marine activities, for example, by using these areas for mussel *Mytilus* spp. cultivating. However, it should also be recognised that adding scour protection can change the seabed substrate and lead to changes in habitat and supporting biodiversity, as well as add to the potential of introducing non-native species.

3.4.2.4. Seabirds

Offshore windfarms can impact birds by displacing them from their feeding, loafing, and nesting areas, potentially forming a barrier to their movement, and/or presenting a mortality risk by collisions. Affecting individuals, populations, migrating / passage seabirds, with any impacts differing depending on the species. Most offshore marine licences now require seabird monitoring to assess changes in how areas are used by birds or to validate collision risk modelling or determine effectiveness of mitigation measures. The MMO (2014) review noted that most licences specified a legal requirement for three years of post-construction monitoring of the potential impacts of developments on birds, although there have been instances of up to five years. However, the MMO is moving away from this and following more targeted monitoring plans which are no longer restricted to 3 years of monitoring (MMO *pers. Comm.*). Methods used to collect the data required to assess the risks have been developed and operating for several years, however, methods are still being further developed . In the past, monitoring was usually restricted to observer data from boats that are necessarily limited in space and time. In the present, Digital Aerial Surveys (DAS) is the standard. There are, however, many studies on the risks to specific species, including pink-footed geese (*Anser brachyrhynchus*), many of which are publicly available and have been used to derive general recommendations by, for example, NatureScot[56].

[56] https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/onshore-wind-energy/wind-farm-impacts-birds

3.4.2.5. Marine mammals

Not all offshore wind farms have conditions related to marine mammals, but where they do, licences stipulate a requirement to monitor/mitigate for their presence and behaviour. Marine mammal observers from boats and passive acoustic monitoring are used to detect them, within the impact area prior to piling during the construction phase .Monitoring post-construction, i.e., when the windfarm is operational, can be considered when a monitoring plan seeks to investigate marine mammals' distribution/ behavioural effects because of construction and/or operation. Since marine mammals can use large spatial areas, and often remain in specific areas for only short periods of time, data to assess the possible impacts of a particular development are sparse and difficult to understand with any degree of certainty. Studies concluded that levels of underwater noise can negatively impact their behaviour causing changes in resting, breathing, diving patterns, vocalizations, changes between mother-infant spatial relationship and avoidance behaviour. Masking due to underwater noise can interfere with social interaction and communication. Physiological impacts can be Temporal Threshold Shift (TTS) and Permanent Threshold Shift (PTS). This can affect marine mammals at individual and population levels, (Palmer et al., 2019). Consequently, the potential for negative impacts due to elevated levels of underwater noise of offshore windfarm developments to marine mammals can be approached through marine mammal management units (MUs), environmental impact assessments (EIA) and Habitat Regulations Assessment (HRA). Several options are then available to monitor the impact of underwater noise on marine mammals such as noise propagation models, fleeing speeds, MM species-specific sensitivity and noise exposure criteria, impact ranges and effects of mitigation measures. However, these forms of project-specific basis assessment can be challenging and supporting a collaborative approach and collecting sufficient datasets over a large spatial and temporal scale would contribute to draw meaningful conclusions with statistical significance[57].

3.4.2.6. Underwater noise

Offshore windfarms are required to monitor underwater noise during their construction (including a period before construction to understand the baseline) and their operation. The MMO review (2014) noted that there were four key requirements in conditioning underwater noise requirements, including installing facilities and submitting plans on how underwater noise will be measured, and consideration of the availability of appropriate baseline data. Several countries provide guidance on monitoring underwater noise as part of the licensing process for offshore windfarms. For example, the Federal Maritime and Hydrographic Agency in Germany provides a comprehensive guidance on how underwater noise should be assessed and monitored, including explicit measurement standards (Aumüller *et al.*,

[57] https://naturalengland.blog.gov.uk/2022/04/13/offshore-wind-best-practice-advice-to-facilitate-sustainable-development/

2013) and protocols (Müller & Zerbs, 2011), which are discussed further in the underwater noise theme below (Section 3.4.4).

Summary
- **Different projects/ developments require different monitoring requirements depending on the results of the impact assessment.** - **Generally, the results are for a small area (zone of direct influence of the development) and limited time series (small number of years).** - **There is limited sharing of data or wider evaluation.** - **Data could not easily be incorporated into strategic monitoring programmes due to lack of standardisation across receptors.**

3.4.3. Aggregate extraction

Each year, the UK marine aggregate dredging industry produces approximately 20 million tonnes of sand and gravel (aggregate) from licensed extraction areas located around the coast of England and Wales (Tillin *et al.*, 2011). Dredging for aggregate extraction can create localised environmental impacts, such as changes in seabed topography, sediment composition, and benthic fauna, and is therefore subject to Environmental Impact Assessment and ongoing monitoring (Cooper & Barry, 2017).

3.4.3.1. Physical processes

Before its extraction, licences require bathymetric surveys to assess and subsequently monitor the depth of the aggregate to ensure there is sufficient material for dredging, and to allow re-colonisation following cessation of the dredging.

3.4.3.2. Benthic ecology

Aggregate extraction licences routinely permit 15 years of activity and require monitoring every five years. An updated approach to monitoring and managing aggregate extraction to minimise impacts on benthic communities was introduced following Cooper (2013), which set out a “regional approach” to monitoring the impacts of aggregate extraction sites. Cooper (2013) collated relevant benthic data and developed a mechanism for their ongoing storage and updating. This monitoring approach, which forms the basis of the marine aggregate industry’s Regional Seabed Monitoring Programme[58], has both improved the sustainability of dredging, by ensuring seabed conditions remain suitable for recolonization, and reduced compliance monitoring costs. Through statistical analysis, sediment tolerance envelopes were developed for species and benthic communities that allowed developers to sample

[58] https://doi.org/10.14466/CefasDataHub.34

and measure changes in particle size distribution, rather than carry out more costly benthic surveys. Comparison of these particle size distributions through time and in contrast to natural variation in particle size distributions from sites outside the area dredged, allows any changes to be viewed at appropriate spatial and temporal scales (Cooper & Barry, 2017). While this regional approach to monitoring requires aggregate companies to work together, it has demonstrated clear advantages to the companies and the industry, including reduced costs, data standardisation (so reducing the need for collecting additional data due to data not being shared or not being comparable), and with potentially better outcomes for the natural environment. However, there are limitations such as gaps in coverage of data due to the focus being on developments or designations or focusing on infaunal biota and therefore hard substrate data may be underrepresented. As such, use of these tools requires their limitations to be understood and caveats noted in any assessments, whether local or strategic level, to put the results into context.

3.4.3.3. Fish

Through its modification of the seabed, aggregate extraction could have important consequences on fish populations, for example, by damaging or removing their spawning habitat. Given the high risk of direct habitat loss, consideration of fish habitat is and has been a required feature of aggregate extraction licence conditions (Cooper & Barry, 2017). Nevertheless, there are number of possible indirect effects of aggregate extraction on fish population abundances and behaviours, including underwater noise, and sediment disturbance causing increased turbidity, although the realised impacts will depend upon the ecology of the individual fish species (Waye-Barker *et al.*, 2015). In recognition of this, fish catch data, primarily from surveys, have been explored as a possible index of the impacts of different phases of aggregate extraction (Stelzenmüller *et al.*, 2010). Findings from such studies suggest that different fish species are affected by aggregate extraction differently, such that their relative abundance in the fish community composition could be a useful indicator to support the sustainable development of marine spatial plans.

3.4.3.4. Other considerations

There is little known about the potential impacts of aggregate extraction on the status of seabirds and marine mammals (but see Todd *et al.*, 2015), although any effect on the abundance of fish stocks, locally or more widely, could affect the competitive interactions between them and the commercial fishing industry, as discussed above.

Summary
- **Whilst there are project/ site specific differences, generally the Aggregate industry in England employ standardised monitoring and assessment techniques.**

- **Generally, the results are for a small area (zone of indirect influence of the development) and limited time series (small number of years).**
- **Data are shared more readily that other industries.**
- **Licence holders, where there are multiple sites within a region, already pool resources to undertake strategic/regional monitoring and assessments.**
- **Data could be used to inform strategic monitoring programmes depending on the hypothesis and data required.**

3.4.4. Underwater noise

The impacts of underwater noise on marine system function and health have not been fully appreciated until recent decades, perhaps growing as sources of underwater noise, such as extraction industries and renewable energy developments, have expanded. Underwater noise is now an internationally recognised threat to the function and health of marine systems and is becoming well monitored. The UK, via JNCC, reports annually to the OSPAR Secretariat to location of noise associated data (from sources such as impact pile driving, geophysical surveys, explosives, military related sonar, and some acoustic deterrent devices). The programme enables the spatial and temporal distribution of anthropogenic impulsive sound activity (and trends in this activity) to be quantified. Contracting Parties report data for a given year from national impulsive noise registries to the OSPAR Impulsive Noise Registry. The Impulsive Noise Registry collects data on impulsive noise activity meeting the criteria for inclusion. These criteria include sound source level thresholds above which it is considered that anthropogenic sound may have harmful effects on marine fauna (see Agreement 2014-08 for specific threshold criteria). The data recorded include the type of activity (seismic survey; pile driving; explosion; sonar; acoustic deterrent device), location of each activity (as a single point or polygon area), and the days on which the activity occurred. These basic data enable the computation of the indicator, whose unit of measurement is Pulse Block Days (PBDs). PBDs record the number of days and their distribution within a calendar year that anthropogenic impulsive activity (meeting the criteria) occurred, within a defined spatial unit. For the Common Indicator, this spatial unit is the ICES statistical sub-rectangle, which covers a large spatial scale, which may be too large (i.e. too coarse a scale) for specific consideration of the response of a receptor to underwater noise. Additionally, Contracting Parties may opt to record more detailed information on the activity (e.g., estimated sound source level) and any source mitigation methods (e.g., the use of a bubble curtain) which were applied.

To provide a coherent approach to underwater noise monitoring in the UK the Good Practice Guide for Underwater Noise Measurement was published by the National Physical Laboratory (Robinson et al., 2014). The report provides guidance on the best practice for in-situ measurements of underwater sound, for processing the data and for reporting the measurements by using appropriate metrics. Allowing easier comparison of measured noise levels and avoiding misunderstandings. Although the report is not intended as a standard, however the guidelines do address the need for a common approach and using the best practice available. The report provides guidance on:

- “identification of the common acoustic metrics for describing underwater noise, including definitions and units, and recommendations of how these metrics should be reported;
- choice of hydrophone and acquisition systems, including calibration requirements and quality assurance;
- deployment techniques, including vessel-based deployments and use of autonomous systems;
- techniques for measuring radiated noise;
- techniques for measuring ambient noise;
- guidance on spatial and temporal sampling;
- data handling and storage;
- data analysis, including metrics, integration periods, statistics, and requirements for auxiliary measurements and metadata;
- uncertainty evaluation”.

Currently, there are many programmes that seek to measure underwater noise in marine systems, including several large and multinational initiatives. The Joint Monitoring Programme for Ambient Noise in the North Sea uses a combination of modelling and measurements from 14 stations around the North Sea to derive high quality maps of the sound levels in the North Sea, while developing standards for the terminology, collection, and processing of acoustic data (by proposing International Organization for Standardization standards) (Robinson, S. P., Lepper, P. A., & Hazelwood, 2014; Kinneging, 2019). Similarly, the National Physical Laboratory, in collaboration with the National Measurement System, The Crown Estate, Marine Scotland and the Scottish Government, provided a Good Practice Guide for Underwater Noise Measurements report[59] that provides guidance for in-situ monitoring of underwater noise, for processing data and reporting the measurements using appropriate metrics (Robinson, S. P., Lepper, P. A., & Hazelwood, 2014). The Baltic Sea Information on the Acoustic Soundscape (BIAS) project, involving Finland, Sweden, Poland, Estonia, Denmark, and Germany, deployed autonomous underwater microphone systems at 36 locations to monitor underwater noise and used those data to develop standards for methodologies, noise measurements and signal processing (Verfuss *et al.*, 2016). Similarly, the QuietMed/QuietMed2 programme aimed to coordinate work done by nations around the Mediterranean Sea and thereby better understand and manage levels of protection and conservation status of their shared marine spaces. The programme produced best practice guidelines on continuous underwater noise measurements (Maglio *et al.*, 2018; Vukadin *et*

[59] https://www.npl.co.uk/special-pages/guides/gpg133underwater

al., 2018). There are many other programmes, including one focused on the outer continental shelf (Atlantic Deepwater Ecosystem Observatory Network[60]).

Understanding the effects of underwater noise on marine systems has been focussed on fish and marine mammal populations and behaviours, since these species are thought to be most vulnerable to the effects of underwater noise, however there are potential limitations in the scale that the data are collection in relation to the responses of the receptor animals. Other targeted monitoring programmes for fish and marine mammals can assist with addressing this limitation.

3.4.4.1. Fish and marine mammals

There are several projects designed to better understand the effects of underwater noise on fish and marine mammal populations and their behaviours.

COMPASS[61] is a network of monitoring buoys across regional of Ireland, Northern Ireland and West Scotland and includes a network of 10 acoustic monitoring stations in current and proposed MPAs to collect data on mobile marine mammal species from seals to baleen whales, together with ambient noise. These data will be combined with existing and newly collected data from the COMPASS network to better understand the spatial needs of species of key importance, such as Atlantic salmon and sea trout, and propose areas for their protection. SeaMonitor is a research project studying the seas around Ireland, Northern Ireland, and Scotland. The project aims to deliver five spatial models on basking shark, skate, salmonids, seals, and cetacean distributions and three management plans in the seas around Ireland, Western Scotland, and Northern Ireland and works together with the COMPASS and MarPAMM project. Acoustic array receivers (less than 10) are deployed of the coast of Ireland, while seal tagging also takes place in Northern Ireland. Two gliders are deployed to go back and forward between the coast of Ireland, Northern Ireland, and the coast of West Scotland. Further there are seven designated areas that use a complex acoustic array receiver (more than 10). SeaMonitor allows the extension of the existing network of oceanographic models and smart buoys from the sister projects COMPASS and MarPAMM, creating a physical connection by using a line of acoustic receivers running between Ireland and Scotland.

The Joint Framework for Ocean Noise in the Atlantic Seas[62] is an INTERREG Atlantic Area funded project involving Ireland, UK, France, Portugal, and Spain that aims to derive regular noise risk maps based on the key marine species, made available through an online visualisation tool, and accompanied by 5 case studies on the impacts and effects of

[60] https://nopp.org/projects/adeon/
[61] https://compass-oceanscience.eu/compass-marine-management-areas-interreg/
[62] https://www.jonasproject.eu/

underwater noise, including ship quieting methods, seismic surveys, offshore wind energy devices and acoustic deterrent devices in aquaculture.

Specific to marine mammals, the East Coast Marine Mammal Acoustic Study[63] uses acoustic recorders at 30 locations off the east coast of Scotland to detect echolocation clicks and ambient noise to better understand space use of harbour porpoise and dolphin species over time. The Enhancing Cetacean Habitat and Observation[64] aimed to better understand and reduce cumulative effects of shipping on whales throughout the southern coast of British Columbia, including the production of noise maps in support of the recovery of the southern resident killer whales. Data on marine mammals have also been collected by the Sea Watch Foundation's Cardigan Bay Monitoring Project and the Small Cetacean in European Atlantic water and the North Sea[65] (SCANS) family of projects (Hammond *et al.*, 2013).

Since marine mammals can use large spatial areas, and oftentimes remain in specific areas for only short periods of time, data on underwater noise levels could be used in lieu of actual observations of fish catches and marine mammal sightings data. However, like other datasets, the data can contribute towards a current baseline, and as the baseline shifts each year then this context will be useful to a strategic approach

Summary
- **Different areas and activities each year.** - **No evaluation undertaken** - **Data can contribute towards a current baseline and shifting baselines**

3.4.5. Cross-cutting themes

3.4.5.1. Policy

The marine environment is intrinsically linked to UK Government strategies around areas such as biodiversity protection and environmental status, wind energy production, and carbon reduction. As a result of its potential to contribute to these important policy areas, there are a number of key targets associated with the marine environment. UK Government has committed to protecting 30% of its seas by 2030 in a way that restores and enhances nature (the Global Ocean Alliance 30 x 30 initiative). The Government has also committed, under the UK Marine Strategy, to the achievement of Good Environmental Status covering a wide range of marine species and habitats to support "*clean, healthy, safe, productive and*

[63] http://marine.gov.scot/information/east-coast-marine-mammal-acoustic-study-ecommas
[64] https://www.portvancouver.com/environmental-protection-at-the-port-of-vancouver/maintaining-healthy-ecosystems-throughout-our-jurisdiction/echo-program/
[65] https://scans3.wp.st-andrews.ac.uk/

biologically diverse seas". Net zero targets include cutting emissions by at least 68% by 2030, a fully decarbonised power system by 2035, and a binding target to reach net zero emissions by 2050. Linked to this, the recent British Energy Security Strategy published in April 2022 increased targets for offshore renewable energy generation by 25% taking UK ambition for offshore wind capacity to "*up to 50GW by 2030, including up to 5GW of innovative floating wind*". This increase in offshore wind targets was accompanied by a commitment to reduce associated consenting times "from up to four years down to one year". These few, but significant examples show that policy requirements are changing and will need to be kept central to any strategic programme which means adaptive approaches need to be integral to any such programme.

These policies and targets sit alongside existing marine sector developments and activities which have their own expansion ambitions such as fisheries, ports, shipping, oil and gas, and telecommunications. Some of these could lead to competing demands on sea areas where the differing ambitions are incompatible with one another. For example, marine protection, trawl fisheries, and subsea cables. With the increased demand for access to marine space and resources, it is essential that a strategic approach is taken to the collection of data to support effective management of the marine environment to ensure that the best use is made of the available space.

3.5. International Obligation Reporting (and Data)

This section provides a summary of the data the UK are obliged to submit on an annual basis to international convention secretariats.

3.5.1. Disposals

The UK reports annually to the OSPAR and London Convention/ London Protocol Secretariats (LCLP) on the volume of material disposed of to each designated disposal site and the contaminant loading (based on the concentration of contaminants in samples and tonnages disposed). Note this only refers to the amount of material disposed to at disposal sites, not the amount dredged/removed. These figures then feed into international assessments regarding the amount of contamination potentially being released into the marine environment based on the UK's national action levels.

The data themselves cannot be directly used for strategic monitoring because the sample regimes, dredge areas and requirement to dredge change year and year. Therefore, no trend assessments can be undertaken on the data and given the data are to report what has happened in the previous calendar year, there is no requirement on the licence holders to vary the reported data. However, like other datasets, the data can contribute towards a current baseline, and as the baseline shifts each year then this context will be useful to a strategic approach. Note the data should be used in combination with the disposal site monitoring (Section 3.3.11).

Summary
- **Different areas are dredged and disposed to every year.** - **Different quantities are disposed of every year.** - **Different analyses/ monitoring undertaken every year** - **No evaluation undertaken** - **Data can contribute towards a current baseline and shifting baselines.**

3.5.2. Offshore Renewable Energy

The UK reports annually to the OSPAR Secretariat the status and details of each offshore renewable energy related installation including:

1. development name
2. location (shapefile accompanies the excel spreadsheet)
3. distance from the coast
4. device type
5. number of devices
6. current status including those in the planning stage
7. capacity
8. foundations type
9. water depth
10. height
11. environmental impact information
12. additional remarks

The data reports are accompanied by relevant GIS shapefiles and are loaded into the OSPAR Database on Offshore renewable energy developments.

As above, the data are not specifically designed to inform strategic monitoring nor to answer strategic monitoring questions, however, they can be used towards understanding the current baseline, and as the baseline shifts each year then this context will be useful to a strategic approach and can be used to inform cumulative impact assessments and marine spatial planning

Summary
- **No evaluation undertaken** - **Data can contribute towards a current baseline and shifting baselines**

3.5.3. Carbon Capture, Utilisation and Storage (CCUS)

Under the LCLP, there is a requirement to report any CCUS projects. At present there are no applicable projects that require reporting however the requirement is there for future developments. As per the renewable energy data, the data will not be specifically designed to inform strategic monitoring nor to answer strategic monitoring questions, however, like other datasets, the data can contribute towards a current baseline, and as the baseline shifts each year then this context will be useful to a strategic approach and can be used to inform cumulative impact assessments and marine spatial planning.

Summary
- **No data from the UK yet** - **No evaluation undertaken** - **Data can contribute towards a current baseline and shifting baselines**

Overall, there are many different examples of monitoring programmes at varying spatial and temporal scales. We have reviewed these in the above sections however, each monitoring programme has considerations that can be brought together into a single programme. However, no single programme to date has fully met the requirements of strategic monitoring as this is the first time a comprehensive definition and criteria have been brought together, although the Scottish RAGs, such as the FTRAG are the closest we have to meeting the criteria. The next steps would be to consider the strategic research questions and utilise the monitoring programmes as a basis for future monitoring and assessment.

4. Concluding Remarks and Next Steps

This report summarises the work to date undertaken to define the term ‘Strategic Monitoring’ and to collate other strategic approaches from the UK and internationally based on literature review, semi-structure interviews and workshops. From the review of other approaches, there are some datasets that would lend themselves more readily than others for answering a strategic level question however, ultimately it depends on the question being asked. Other approaches, whilst not directly applicable to strategic monitoring, e.g., international reporting, would provide useful context for understanding the baseline and the shifting baseline(s).

From interviews and workshops, it was agreed that strategic monitoring is a very important but complex topic, and the key is to develop a clear hypothesis/es or overarching research question(s) that address policy, evidence gaps, or change in the environment deemed meaningful (rather than just statistically significant). Once set out, and only at this point, should the monitoring then consider the next steps such as scale, analyses, and data (types and methods to collect). Together with the other considerations covered in the report, it is recommended that a strategic monitoring approach should be developed to ensure that future monitoring is standardised, appropriate, representative, and robust. Due to the challenges (access, cost etc) of applying a strategic monitoring approach, sentinel monitoring may want to be considered to either monitor those sites that are not easy to access or for areas that could be used as control sites. To develop such an approach, it is recommended that a strategic monitoring framework is first implemented, which will provide stages to work through from inception to evaluation that can be applied generically, at different scales including internationally.

Further specific recommendations set within such an overarching framework for strategic monitoring of OSW are:

- Set out key targeted questions that properly frame strategic monitoring questions for offshore wind farms.
- Identify who are the responsible parties for funding/carrying out the strategic monitoring and who is responsible for reviewing and signing off.
- Identify key evidence gaps associated with offshore wind related topics that could be addressed using a Strategic Monitoring Approach (a non-exhaustive list of evidence gaps has been summarised in Appendix VII: Summary of Offshore Wind related topics that could be addressed using a Strategic Monitoring Approach).
- State clearly and explicitly hypotheses or research question(s) pertinent to the predicted impact.

- Define the required data to address the question(s) (at the right spatial and temporal scale).and who is required to collect, collate, and analyse the data, and publish the findings.
- Determine if data exist (in the right format and at right scale) or how the data should be collected and by whom (including minimum requirements of the data, and the ideal to allow trade-off considerations for filling the knowledge gaps).
- Consider how big data[66] can assist with meeting the strategic objective(s).
- Identify pilot studies that can be used to assist in the validation of a strategic approach.

Integrated sustainable management of marine resources, such as natural capital, to allow the provision of marine ecosystem services (including nature-based solutions) is a goal within UK and international policies (e.g. 25YEP; 30 x 30, SDG14). However, much scientific/evidence work, and associated valuation is undertaken using partial or piecemeal approaches, both geographically (i.e. within one geographical region) and thematically (per ecosystem function or service). The challenge of providing the scientific evidence required for integrated sustainable management could be assisted greatly through taking a strategic approach, which will allow better informed decision making, including management trade-offs.

[66] Big data refers to data sets that are too large or complex to be dealt with by traditional data-processing application software but offer greater statistical power. The OneBenthic app is an example of Big Data and how it can be used for considering significant impacts of human activities within natural variability.

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Appendix I -Project brief

Project background

The UK has world-leading ambitions for expanding the offshore and marine renewable energy sector, with a clear commitment to both fixed and floating offshore wind, and the associated subsea cabling, and future hydrogen production and storage, across much of the UK territorial waters. However, the knowledge gained from the past two decades of offshore wind development, and the ongoing monitoring and research to meet current licensing requirements, has relied on the collection of site or project level data (Willsteed, Jude, *et al.*, 2018) for a small number of specific variables on a few specific receptors. Such data are required to assess and monitor potential impacts identified during the mandatory environmental impact assessment process. These data are, however, limited in their ability to provide the understanding of what the physical and abiotic changes that are occurring mean in terms of the scale of change (i.e., whether the changes actually represent significant impacts) to cause ecological consequences, which lead to changes in the ecosystem services that we obtain from our aquatic environment (Gill *et al.*, 2020a; Wilding *et al.*, 2017a). The types of changes, and the how they affect the ecosystem components, are important to monitor over the most appropriate spatial scales and temporal scales. This is essential for understanding and predicting the changes that will occur in relation to the future scale of offshore wind development and the rate of planning and installation to support the UK's 2030 renewable energy and wider Net Zero targets and sustainability aspirations.

A strategic approach is therefore necessary. Such an approach requires an agreed set of elements covering a wide, holistic scope, which can be applied at a local scale and be extended to a regional scale (Willsteed *et al.*, 2017; Willsteed, Birchenough, *et al.*, 2018). Furthermore, to understand cumulative effects of multiple turbines and wind farms, in terms of how they may impact ecosystem components, also requires the appropriate temporal scales to be factored in (Gill *et al.*, 2020; Willsteed *et al.*, 2017; Willsteed, Birchenough, *et al.*, 2018).

Aims and Objectives

(1) This project aims to develop the rationale and basis for a new strategic monitoring approach, built around the key elements of assessing change at relevant and meaningful spatial and temporal scales. In this context, 'meaningful' relates to ecological changes that will have consequences to the status of the ecosystem and, therefore, affect the ecosystem services obtained from the marine and coastal environment. This strategic approach will address how to monitor and understand what may be gained or lost by using the UK's waters for offshore wind development, which will address the 'so what' questions that have to be addressed to achieve effective sustainable management and preserve future opportunities.

(2) The outputs will assist, in-part, in filling evidence gaps associated with determining the ecological status of the marine and coastal waters and will feed into considerations such as marine spatial planning, the UK Marine Strategy and other related policies and legislation.

Appendix II – expert semi-structured interviews

Questions emailed ahead of semi-structured interviews

- How would you define strategic monitoring?
- In your area of expertise, what specific considerations should strategic monitoring account for? Think definition…
  - And in relation to offshore wind farms?
- In your area of expertise, how would you ideally do strategic monitoring? Think approach…
  - And in relation to offshore wind farms?
- Can you recommend any reports/papers about strategic monitoring for your area?

Table 1 Details of Cefas experts interviewed as part of the research for this project.

Topic area	Specialism	Interviewee	interviewer
Benthic ecology	Offshore renewables	Jackie Eggleton	SG
Benthic ecology	Aggregates	Keith Cooper	SG
Fisheries	Migratory fish	Alan Walker	SG
Fisheries	Offshore renewables	Louise Cox	JL
Underwater noise	Underwater noise	Rebecca Faulkner	SG
Marine mammals	Marine mammals	Simone de Winter	JL
Physical	Substrate	Jon Barry	SG
Physical	Oceanography	Jon Rees	JL
Biogeochemistry	Biogeochemistry	Ruth Parker	JL
Strategic assessment	Fisheries Modelling	Will le Quesne	SG
Strategic assessment	Biogeochemistry/ Water quality	Michelle Devlin	SG
Strategic assessment	Physical Modelling	Stephen Dye	JL
Strategic assessment	Offshore renewables	Daniel Wood	SG
Modeller	Ocean Modelling	Liam Ferdinand	JL

Appendix III – workshop details

Defra/ALB group meeting

- Date: 15 February 2022
- Location: Microsoft Teams
- Attendees: Natural England; JNCC; Defra.
- Hosts: Defra; MMO; Cefas

Project Steering Group (including experts and stakeholders) meeting

- Date 1 March 2022
- Location: Microsoft Teams
- Attendees: Natural England; Pathways to Growth; Defra; SSE contractor; Ørsted; RWE; Flotation Energy; Wildlife Trusts; Crown Estate; Planning Inspectorate; JNCC; JKG Consultancy; Scottish Power; Vattenfall; Renewable UK; Res-Group
  Hosts: Defra; MMO; Cefas
- **Summary Notes**

These are the notes of the meeting and what was discussed. Note, they are added here to provide a record of the discussion within the group during the workshop, rather the main points and any actions.

- Why are socioeconomics included, as traditionally in OSW post-construction monitoring this does not come into data collection? Are the socio-economic elements related to coastal communities/fishing?
    - These elements will be of increasing importance, so it is important they are reflected.

- The definition is missing reference to a feedback loop from feeding monitoring information back into decision making.

- Following the aggregate example, implementation may need to be industry led.
    - The definition will need to be broad enough to be applicable to a range of different stakeholders.
    - Having a broader definition of strategic monitoring may be difficult if it is trying to encompass a range of different sectors.
    - The stakeholder group involved in these discussions is largely offshore wind focussed, if the definition is to be broader then there is a need to test it with other groups (particularly mNCEA) to ensure that there is no duplication/overlap.
    - The discussion on how the mechanism work will come later in the project.

- Does compensation need to be included in the definition?
    - Monitoring should seek to understand if compensation measures are effective and if not, what should replace them.
    - Assessing status (the impact of an activity on a particular receptor) doesn't necessarily capture everything that monitoring would be investigating – such as flight height of data informs collision risk modelling that then informs population viability.
    - The definition needs to cover the entire IROPI/derogation process – will strategic monitoring inform thinking about alternatives?

- Evidence gaps are a huge barrier for implementing the mitigation hierarchy in any industry
    - Strategic monitoring presents an opportunity to gain momentum for filling gaps.
    - There is an opportunity to start to move the question along rather than each monitoring process repeating the same questions without providing any answers.
    - The element of the definition in grey could be replaced with 'to allow effective measures.'

- Does the definition cover the strategic element sufficiently?
    - Concern that if the word strategic is removed from the definition, then it reads just as a definition of site-specific monitoring – is there something that could be added to make the strategic element more explicit?
    - Look to examples of monitoring for UK Marine Strategy and whether this is classed as strategic.

- Are the spatial and temporal aspects of the definition benthic orientated? If so, how are highly mobile species and seabirds, which are not tied to a project area, accounted for?
    - Using migratory fish as an example is it possible to look where fish are and define a change in numbers/biomass?
    - Examples will be looked at in more detail during the next stage of the project.

- Example of monitoring impacts on seabirds
    - In all SPA's populations are declining and we don't understand why
    - What is lacking is an understanding of how population changes are affecting what is done in terms of mitigation - are populations moving because they want to or because of pressures?
    - Monitoring question is 'are offshore wind farms causing the change?'

- Monitoring is driven by indicators/regulatory landscape

- How does site specific monitoring feed through into strategic monitoring? (there is a risk that developers see this as an opportunity to overlook project level monitoring).
- How do we bring together data collected for one requirement into a strategic approach?
- How do we help industry collect and manage data?

Appendix IV – Internal Cefas Workshop Attendees

Attendee	Specialism	Breakout group
Adrian Judd	International/ Ecosystem Assessment	2
Alan Walker	Fisheries Scientist	3
Andrew Gill	Facilitator / OMRE assessment	2
Clare Leech	Policy	3
Ellen McHarg	Environmental Economist	2
Gordon Copp	Fisheries Scientist	3
Jemma Lonsdale	Facilitator / cumulative assessment	2
Joe Perry	Facilitator / OMRE advice	3
Jon Barry	Statistician	3
Jon Rees	Hydrodynamic Modeller	2
Keith Cooper	Benthic Ecologist	2
Liam Fernand	Hydrodynamic Modeller	1
Michelle Devlin	International/ Ecosystem Assessment	1
Phil Davison	Fisheries Scientist	3
Rachel Mulholland	Facilitator / OMRE policy and planning	1
Rosalyn Putland	Underwater Noise	1
Sarah Watts	Facilitator / Fisheries advisor	1
Simone de Winter	Marine Mammals	1
Stephen Dye	Modeller	2
Stephen Gregory	Facilitator / statistician	3
Tea Basic	Fisheries Scientist	3
Tiziana Luisetti	Environmental Economist	2
Will Le Quesne	International/ Ecosystem Assessment	2

Appendix V – Internal Cefas Workshop Agenda

Internal workshop – Strategic Monitoring

Agenda – 25th April 2022 1.30-4.30

1:30 – Introduction to project (20 minutes) This will include a brief summary of works to date and the report where outputs of the workshop discussions will be included.

1:50 - Introduction to Session 1 - (10 minutes) This will explain the technology which will be used, and the expectations of the input required and the etiquette.

2:00 – Break into separate discussion groups – **Session 1** (45 minutes) (3 groups, approx. 8 participants per group) (generally themed by speciality where possible)

2:45 – 3:30 Break (45 minutes) –At the end of this session each participant will identify what they consider as the most important consideration for strategic monitoring and share with their group via whiteboard software. The chair will then input these considerations into Slido for participants to vote on the top 3 considerations after the break.

3:30 – 4:15- **Break into separate discussion groups** - **Session 2** (45 minutes) (3 groups, approx. 8 participants per group) (generally themed by speciality where possible) - Chance for participants to vote on what they consider the top 3 considerations. These top 3 considerations will then be used as the focus for each group.

4:15 – 4:30 - Summary of outputs from Session 2 discussions, next steps and closing statement (10 minutes)

4:30 End of workshop

Appendix VI – Internal Cefas Workshop Pre-Workshop Information

Strategic Monitoring review

Internal Cefas Workshop - 25th April 2022

Project background

Cefas have been funded by the Department for Environment, Food & Rural Affairs (Defra) to undertake a review of what is meant by 'strategic monitoring' in the context of assessing the impacts of human activities on the UK marine and coastal environments. The main driver for this project was to develop an approach for implementing strategic monitoring of offshore wind and associated infrastructure development and their interactions, effects and trade-offs within the marine and coastal environment and the ecosystem services they provide within English (and Welsh) waters.

At the workshop the topic areas will be discussed and covered in detail in the accompanying strategic monitoring report.

Literature review

The strategic monitoring report is currently in progress, so we are not able to provide a definitive list of resources which are being considered at this time. However, please think over the following questions.

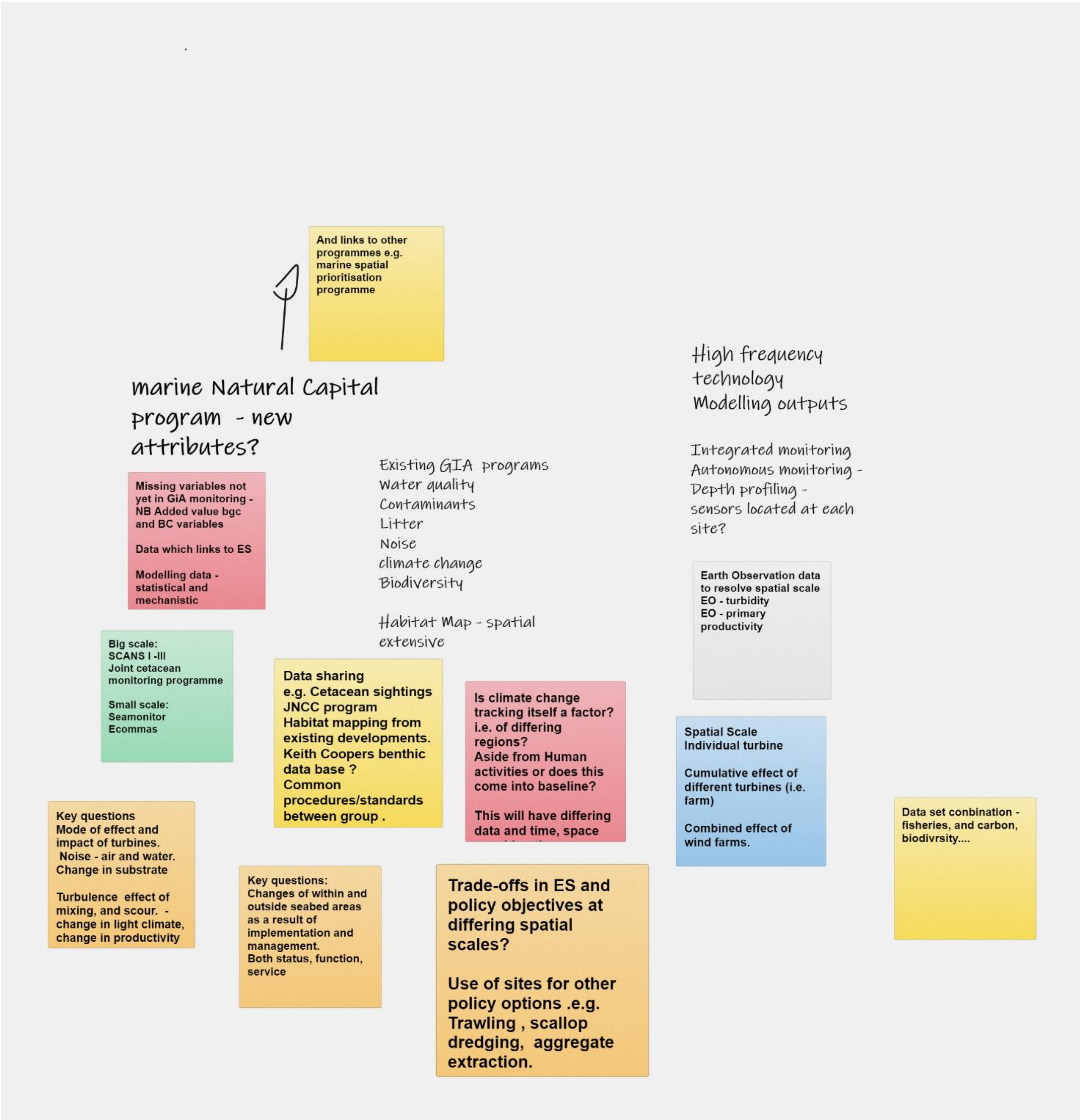
Questions to consider ahead of the workshop:

- What data sets need to be included in the strategic monitoring review?
- What adaptations do we need to make to these sources in order to make them more valuable for strategic monitoring purposes?
- What are the key questions for offshore wind that Strategic Monitoring needs to/can address?
- Are there any data sets which could be combined to be more valuable for strategic monitoring?
- What areas need further consideration?
- What are the gaps in available data?

Appendix VI – Internal Cefas Workshop Breakout Session Outputs

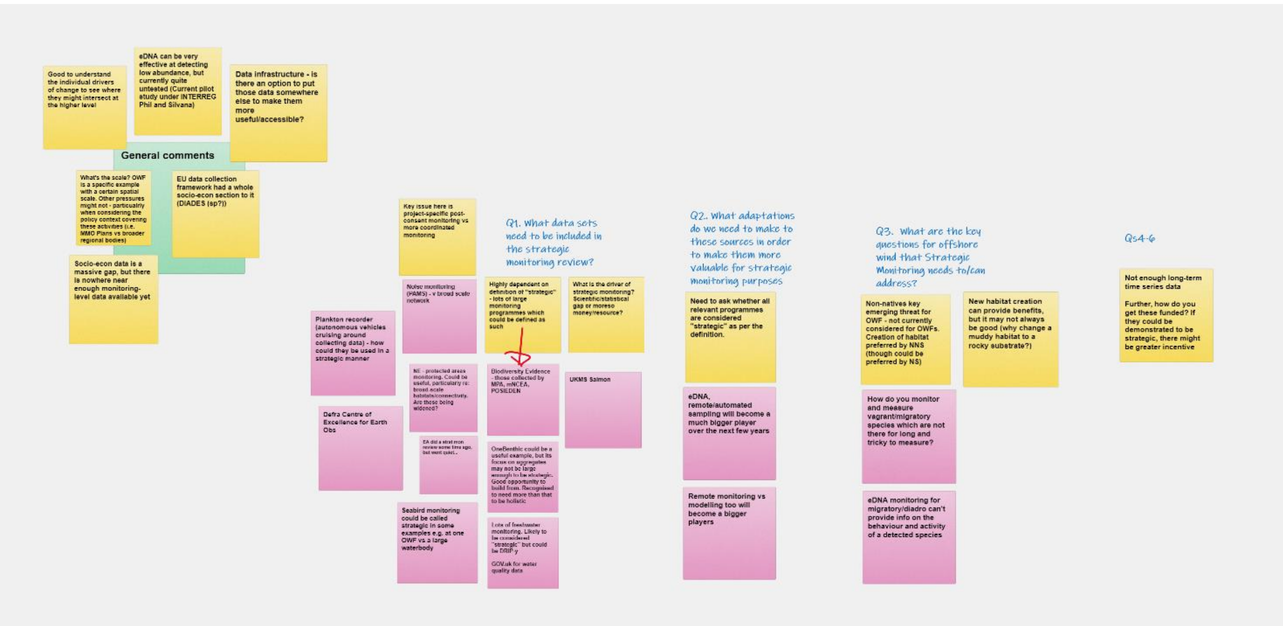
Breakout Session 1

Group 1:



Group 2

Group 3 (green - general thoughts; yellow - question specific thoughts; purple/red – examples)



Breakout Session 2

Group 2

Group 3


Data mobilization, starts with identifying the data and owners; then agreeing access and use; then how to access those data
MEDIN - how to enable the integration of concurrent datasets
Data Manager input here would be essential. Need to acknowledge consistency of info and ready to share
Ocean Tracking Network (OTN) and European Tracking Network (ETN) are fish tracking programmes that aim to facilitate data sharing. works in progress.
ICES Data Unit has the aim to make all data used in fish stock assessments publicly, through their TAF (Transparent Assessment Framework) process. Challenge may be that many of those data are
Use surveys of the seafloor to predict possible marine communities in that area and potential impact. Actually, there are lots of existing surveys on marine life which could be used
Integration of Data into Strategic Monitoring
Not only in using the data, but making it visible/accessible can provide benefits. Greater access and greater trust
Who's the convener, or data "broker" of all this? Trust is a key barrier and opportunity
Citizen Science - incorporation of smaller strands into broader strategies e.g. recreational fishers, divers?
Bottom-up rather than top-down - Keith was only able to do that due to existing datasets
Data purpose is important re: policy priorities vs broader scientific targets
Policies can define how/to what extent data can be used in assessments
Disconnect between available technology and the needs for specific data in terms of both licensing/assessments and policy needs
How will the quality of data be incorporated?
Difficult to assign a potential "broker". ICES? OSPAR? Alan describes multilateral marine governance as a real-world Marvel Cinematic Universe
Practicality of data consolidation from multiple data-holding parties. Specify which data are required and for what purpose, requesting only those most essential (North atlantic Salmon data call)
New technologies require validating for certain uses so that they can be used appropriately for policy
ICES principle of transparent assessment framework - all stock assessment framework have to be available. But most of these data are owned by separate countries

Appendix VII: Summary of Offshore Wind related topics that could be addressed using a Strategic Monitoring Approach

During the workshops, and literature review, key evidence gaps were raised associated with offshore wind, which could be addressed through a strategic monitoring approach. This non-exhaustive list of evidence gaps has been summarised below. Note, that for some specific gaps identified, it is suggested that these could be integrated within wider strategic monitoring programmes. This may mean several specific projects or methodologies will need to be undertake, however, importantly they will be under a strategic programme of evidence gathering.

Biological & Ecological

- Wide-scale surveys of inshore and offshore benthic habitats should be undertaken that integrate standard benthic biodiversity measurements along with measurement of benthic rate processes.
- Sentinel locations should be established for long-term whole ecosystem monitoring to support research in process understanding of links between development status, ecosystem service delivery and benefits.
- The consequences to benthic ecological processes and functions can be affected due to direct impacts (installation of infrastructure, removal through removal of seabed) or indirect (smothering, changes in sediment composition).
- Operational indicators to report on pelagic resources should be developed. Substantial progress could be made on this with existing datasets through dedicated modelling and research.
- Collection of additional parameters on pelagic resources, such as picoplankton and TOC, that can be integrated into existing at-sea survey programmes (with limited modification) could be implemented.
- Fisheries can be impacted directly (removal of spawning habitat) or indirectly (underwater noise, increased suspended sediment)
- Shellfish could be impacted (removal of spawning habitat or removal of individuals through seabed removal) or indirect (underwater noise, increased suspended sediment).
- Marine Mammals can be impacted by the presence of human activities/ manmade structures, underwater noise, and EMF, either directly or indirectly. A direct impact from elevated underwater noise levels during the construction phase can alter their behaviour for example changes in dive patterns and breathing. An indirect impact can be that there is a change in prey behaviour or abundance due to the prey response to the elevated underwater noise levels.
-
- An UK wide marine mammal monitoring strategy with a collaborative approach and collecting sufficient datasets over a large spatial and temporal scale would contribute to meaningful conclusions with statistical significance.

- Impacts on birds can be displacement from their feeding, loafing, and nesting areas, potentially forming a barrier to their movement, and/or presenting a mortality risk by collisions. Affecting individuals, populations, migrating / passage seabirds, with impacts differencing depending on the species. In addition some species are attracted to OWF presumed to be related to increased feeding opportunity, highlighting the need to clearly define what changes will occur and in which direction (positive or negative or neutral).
- Improve and increase frequency of monitoring of seabirds to allow earlier detection of trends for species of interest to understand impacts of pressures. Especially, the risks of the impacts that are occurring such as collision risk by modelling parameters and actual collisions, to ensure that the evidence meets the need for understanding meaningful change at the population level.
- The potential for benefits, such as artificial reef effect should also be included to ensure the balance of understand changes to the marine environment fit with the context of strategic approaches.

Physical

- Sentinel locations should be established for long-term local and regional monitoring to support research in process understanding of links between biological status, ecosystem service delivery and subsequent benefits.
- Underwater noise is generated predominantly from the construction of the OWFs due to piling (for fixed turbines) and there are questions over operational noise for both fixed and floating.
    - Can this be mitigated by using different structures?
- Sediment processes can be impacted (which in turn affects erosion at the coastline, wave height leading to flooding) through the deepening (seabed removal) or shallowing of water depths. Scour can also occur around the infrastructure changing sediment composition and sediment processes further afield.
- Biogeochemical processing in sediments around turbines, across arrays and cable routes.
- Electromagnetic fields can interfere with organism behaviour, e.g., foraging by elasmobranchs.
- Structures provide new habitat/substrate for some species, e.g., bivalves, how consistent is the colonisation across wind farm arrays and over regional areas where multiple wind farms are located?

Socio-economic

- Dedicated social science surveys should be conducted to develop fuller understanding of the benefits of cultural services, and links to natural asset condition, at both a place-based scale (to determine impact/outcome of changes to asset status) and national level surveys to inform policy direction.
- Social science method development to understand the full cultural benefits of the marine and coastal environment should be supported.
- Climate sensitive indicators of fishery status should be developed.
- Activity recording of <12m vessels should be implemented.
- OWFs can exclude certain activities e.g. fishing, vessel movement
- OWFs could act as a protection measure for fish and other species if fishing is not permitted

- OWFs can be objected against if they are considered to be visually unappealing (affecting the seascape)
- Construction of OWFs can affect leisure and recreation with the installation of cables on beaches etc.

Synergies

- Any potential impact can interact with other impact(s), potential resulting in a synergistic impact whose effect might be lesser or greater than their additive impacts.
- Multiple stressor approaches are required and should be encompassed through strategic approaches.

Appendix VIII: Example Projects Linking Strategic Monitoring to Policy

This section provides a summary of the projects that were highlighted to the project team from stakeholders from the workshops. These projects have the potential to link strategic monitoring to policy aims and objectives which may be of interest to Defra.

CAMPUS

CAMPUS explored how to enhance the use of autonomous instruments, combined with hydrodynamic /ecosystem models, to provide a cost-effective marine monitoring system for real time data collection to forecast water quality status around the UK. It developed realistic scenarios for a future UK network, integrating a variety of autonomous vehicles and instrumentation with *in-situ* observations, costed each scenario, and then demonstrated their effectiveness at accurately assessing the status of the UK Seas relating to the OSPAR - Eutrophication assessment. A major outcome of the project was a scenario-based assessment of how well – and with what confidence – different amounts of spatial and temporal data, collected from combinations of fixed stations, autonomous gliders, and satellite technologies, represented the health status of UK sea and their associated financial cost. It was found that inclusion of autonomous instruments in monitoring programmes decreased the number of regions with low confidence outcomes and increased the number of regions with high confidence outcomes. Although these improvements were associated with an increased financial cost, that cost should be offset and overshadowed by the potential financial savings from actions that would be required to maintain good environmental status.

Offshore Wind Environment Evidence Register (OWEER)

The Offshore Wind Environment Evidence Register (OWEER) is the first UK – wide register of that draws together the key evidence gaps around offshore wind environmental impacts as well as research projects recently completed, in progress, and in planning of relevance to reducing evidence gaps. The aim of OWEER is in assisting to prioritise funding for the Offshore Wind Evidence and Change (OWEC) programme of strategic research. The register is also publicly available for wider use to highlight priority evidence gaps, increase understanding of the breadth and scope of the research field, reduce project duplication, foster collaboration, and disseminate project findings. The project is funded by the Crown Estate and run by Defra and JNCC.

The most recent version of the OWEER is Iteration 2[67], covering 2020 onwards. The information used for the register came from relevant organisations. The register focuses on four specific receptor groups: fish, benthic, ornithology and marine mammals. The register further contains some overarching evidence gaps and research projects not specific to one receptor. Evidence gaps are prioritised highlight from high to low priority in relation to consenting risk and topic(s) covered. The prioritisation scores are based on:

1. Potential magnitude for reducing consenting risk
2. Potential for the evidence gap to reduce short-term consenting risk (pre- 2030)
3. Potential for the evidence gap to reduce long-term consenting risk (post- 2030)
4. Evidence gap covers on or more high priority species, habitats, or receptors; or addresses an overarching theme; or has synergy with other projects i.e., fits with other needs.

The prioritisation scoring has been completed by receptor specialists' teams at JNCC and reviewed by the OWEER Project Advisory Group (PAG).

The information provided by OWEER can help identify some of the key evidence gaps that strategic monitoring could set out to cover, together with the data that were collected during recent completed research projects on some of the identified evidence gaps. In particular, the overarching considerations, such as ecological structure, function and processes could be further developed to address strategic level aspects.

Marine Net Gain

Net Gain is a developing concept aimed at providing additional benefit above those of the compensatory measures applied to plans or projects to ensure there is No Net Loss (NNL). Where the variety and/or abundance of species or habitats is increased, this is Biodiversity Net Gain (BNG). BNG is mandatory in the terrestrial environment to mean low water and the aspiration is to deliver it in the Marine environment.

The Natural Capital Committee (Defra, 2018) recommended looking at the environment as an integrated system, meaning that consideration would be given to social and environmental parameters as well as biodiversity to provide Environmental Net Gain (ENG). There is recognition that the concept of ENG offers more than simply compensating for biodiversity loss (e.g., Defra, MMO, Environmental Industries Commission (EIC) Natural Capital taskforce, the Natural Capital Committee (NCC) and wider stakeholders).

Net Gain is usually used to imply Biodiversity net gain which allows for the measures to exceed the original biodiversity or habitat lost through the use of habitat restoration or creation of (ideally) similar habitats with a greater potential of biodiversity and natural capital.

[67] https://jncc.gov.uk/news/oweer-launch/

ENG is the implementation of wider benefits that might affect social and environmental recipients in addition to biodiversity. Although there is no clear definition found, the NCC implies that the focus is in considering the environment as an integrated system. Holistic net gain is like ENG but includes schemes for: awareness raising, environmental education, research, and capacity building.

A project being funded by the Offshore Wind Energy and Change (OWEC), the Marine Net Gain Task and Finish Group[68] and Defra's Offshore Wind Enabling Actions Programme (OWEAP) is developing recommendations for strategic target for Marine Net Gain ensuring that the industry can play a significant role in helping restore marine environments. ABPmer (2021) states that "*The central principle behind 'net gain' is that any biodiversity impacts that arises from new developments, must be offset through the creation and restoration of habitats such that there is at least a net 10% increase in biodiversity overall*". It includes actions that might be taken in the coastal and intertidal areas, in the offshore marine environment, as well those on land that might benefit the marine environment.

In 2021, marine stakeholders were invited to participate in a survey to welcome their views on priority actions for marine restoration and enhancement in UK waters. The findings will help to direct how Marine Net Gain is delivered when it becomes a routine aspect of development and part of the government's economic growth principle Build back Better. The findings will be made available in the OWEC Marine Net Gain Task and Finish Group report. The project should have ended in September 2021. The outcome of this project could help identify what marine net gain is going to look like in the future and how from there on monitoring can take place.

Additionally, Defra launched a consultation in 2022 (Defra, 2022) on the principles of marine Net Gain following a consultation in 2018 on making biodiversity net gain on land mandatory where respondents expressed that these should be extended to marine developments. The consultation proposes a strategic approach to marine net gain considering both environmental and wider gains. The responses from the current consultation will further refine the principles and shape how marine net gain can be implemented in the marine environment.

[68] https://www.abpmer.co.uk/resources/

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We are the government's marine and freshwater science experts. We help keep our seas, oceans, and rivers healthy and productive and our seafood safe and sustainable by providing data and advice to the UK Government and our overseas partners. We are passionate about what we do because our work helps tackle the serious global problems of climate change, marine litter, over-fishing, and pollution in support of the UK's commitments to a better future (for example the UN Sustainable Development Goals and Defra's 25-year Environment Plan).

We work in partnership with our colleagues in Defra and across UK government, and with international governments, business, maritime and fishing industry, non-governmental organisations, research institutes, universities, civil society, and schools to collate and share knowledge. Together we can understand and value our seas to secure a sustainable blue future for us all and help create a greater place for living.

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