NatureScot / JNCC / MSS Workshop to Review the Suite of Marine Biodiversity Indicators for Scotland's Seas

Workshop Report

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October 2022

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This document should be cited as:
Lee, A. (compiler). 2022. *NatureScot / JNCC / MSS Workshop to Review the Suite of Marine Biodiversity Indicators for Scotland's Seas: Workshop Report*. JNCC, Peterborough. [https://hub.jncc.gov.uk/assets/ea78af2f-83bd-4927-849a-5ca4ea91c8d1]

Acknowledgments:
This workshop report was produced in collaboration between JNCC, NatureScot and Marine Scotland Science. Its content is based on summaries of key points made by workshop participants and captured by rapporteurs during the event. Six organisations took part in the workshop: NatureScot, JNCC, Marine Scotland Science, the Scottish Environment Protection Agency, the Scottish Association for Marine Science and the University of Edinburgh. Their contributions are gratefully acknowledged.

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Executive Summary

This report summarises the outcomes of a virtual workshop held in March 2022 to review the suite of marine biodiversity indicators for Scotland's seas. The workshop was planned in collaboration between NatureScot, the Joint Nature Conservation Committee (JNCC) and Marine Scotland Science (MSS). A total of 32 people attended the event from six different organisations: NatureScot, JNCC, MSS, the Scottish Environment Protection Agency, the Scottish Association for Marine Science and the University of Edinburgh.

The aim of the workshop was to review the suite of marine biodiversity indicators currently being used in Scotland, to identify lessons learned in their use, particularly relating to Scotland's Marine Assessment 2020, and to identify opportunities to improve and support future assessment work. The focus was on Scottish marine waters, but the workshop considered a range of indicators from those used as official statistics in Scotland, through to those used for the UK Marine Strategy (UKMS) and OSPAR.

The workshop introduction included presentations on: (i) outcomes from Scotland's Marine Assessment 2020 and the gaps/lessons learned in respect of biodiversity indicators, and (ii) key criteria for consideration in future development of indicators, and the use of indicators in the wider context including for assessments relating to the UKMS and OSPAR.

Breakout groups were established to facilitate discussion on indicators relevant to eight groups: seabirds; non-native species; food webs; extent of physical disturbance to seafloor/special habitats; waterbirds; inshore fish; biogenic habitats and intertidal seagrass; and deep-sea vulnerable marine habitats and deep-sea fish. Each group discussed a series of pre-set questions relating to current issues and future development needs for indicators. These covered a variety of topics including research gaps, issues with data collection and data flows, and potential developments related to monitoring and reporting on climate change impacts and other pressures.

The main output was a series of recommendations from each group relating to the future use and application of marine biodiversity indicators in Scotland (Section 2). A variety of points were made, and recommendations were summarised in Section 3 as follows:

1. Recognise the important role of indicators in marine biodiversity assessment.
2. Clarify relationships between indicators, including more integration to improve interpretation of results and overall assessments.
3. Further develop indicators to improve accuracy and applications.
4. Recognise the requirement for more supporting or contextual research.
5. Explore opportunities to improve existing methods to better understand climate change and ocean acidification effects.
6. Improve opportunities for data collection for better accuracy and interpretation of results.
7. Improve data access for existing activities and pressures data.
8. Improve data flows for easier discoverability.
9. Enhance the role and value of citizen science.
10. Use focused case studies to complement indicator results and highlight local issues.

The workshop report will be published and shared specifically with marine science and policy specialists to inform the ongoing development of marine biodiversity indicators and support future assessment work. This includes Scotland's Seas Data and Assessment Group where these recommendations will support consideration of the next steps for future assessments of the state of Scotland's seas. Beyond Scotland, the recommendations will also feed into future developments for monitoring and assessments under both the UKMS and OSPAR.

Contents

1 Introduction

1.1 Aim and introduction to the workshop

The workshop was held virtually on 3 March 2022 and its aim was:

> *To review the suite of marine biodiversity indicators currently being used in Scotland, to identify lessons learned in their use, particularly relating to Scotland's Marine Assessment 2020, and to identify opportunities to improve and support future assessment work. The focus is on Scotland, but the workshop will consider a range of indicators from those used as official statistics in Scotland, through to UK Marine Strategy and OSPAR.*

The output from the workshop was a series of recommendations relating to the future use and application of marine biodiversity indicators in Scotland, as set out in Section 2 of this report. The workshop was planned in collaboration between NatureScot, the Joint Nature Conservation Committee (JNCC) and Marine Scotland Science (MSS). A total of 32 people attended the event from six different organisations: NatureScot, JNCC, MSS, the Scottish Environment Protection Agency, the Scottish Association for Marine Science and the University of Edinburgh. A list of participants is presented in Appendix 1 and the workshop programme is presented in Appendix 2.

Two introductory presentations provided an overview of marine biodiversity indicators, assessment and reporting, gaps and potential development needs. The plan for the day and expected outcomes were also explained, including the use of breakout groups for more detailed discussion on specific groups of indicators.

1.2 Outcomes of Scotland's Marine Assessment 2020 and the gaps/lessons learned in respect of biodiversity indicators

The presentation on Scotland's Marine Assessment 2020 (SMA2020) introduced the overall assessment and provided an overview of the results for marine habitats and species. The introduction highlighted that SMA2020 is the 3rd state of Scotland's seas assessment and represented a move to ensure a more quantitative approach than was possible for the previous two. SMA2020 is presented via an online portal to ensure greater access to as wide an audience as possible. Key to the assessments are the Scottish Marine Regions and Offshore Marine Regions that ensure a spatially consistent approach. It was highlighted that SMA2020 covers a range of other topics, such as clean and safe, and productive seas, but with the focus for the workshop on the healthy and biologically diverse section.

An overview of the national status and trends of different marine habitats and species was presented, from the results of the North Sea bottlenose dolphin (with few or no concerns) to those for salmon and sea trout and biogenic habitats (with many concerns). A lack of evidence or sufficiently robust assessment criteria were also highlighted for some assessments (e.g. for non-native species). Alongside the national status, where possible, assessments covered regional status and trends, with some also flagging local concerns, or concerns relating to specific species. The need to look beyond the headline points was also emphasised through the example of the variation in national status and trends for different seabird species. Examples of some of the key messages and knowledge gaps were also discussed. Some of the key messages highlighted: insufficient data for some species and habitats, the area of seabed subject to disturbance, and significant changes that have been recorded in the plankton community. The knowledge gaps highlighted the need for better understanding of the implications of climate change, the drivers of declines for some species, and the implications of changes in habitats and species for the wider functioning of marine ecosystems.

1.3 Marine biodiversity indicators in the wider context

This presentation gave an overview of the existing approaches and key criteria to be considered in the development of indicators. Biodiversity indicators are integral tools available to policy and decision makers to evaluate and understand environmental change. They can be designed and applied at different scales, over short- or long-term scales, depending on the policy question and data availability; for example, they can be used to evaluate changes at local level or for wider evaluation of complex trends at regional level.

Use of indicator-led assessments enables the evaluation of progress towards specific targets, objectives or the performance of policy measures in a systematic way. Consequently, their planning and development must take into account the relevant science and evidence base, resources available and scale of implementation, as well as the policy or management questions that need to be addressed.

Indicators are being used to assess and evaluate progress against national and international policies and strategies, for example: i) assessing Good Environmental Status and targets under the UK Marine Strategy, and ii) assessing biodiversity and pressures impacting on wider sea regions under the OSPAR Convention. A summary of marine biodiversity indicators relevant to Scotland's seas is presented in Appendix 3.

2 Key Recommendations for Specific Groups of Indicators

2.1 Breakout group discussions

Eight breakout groups were established as follows, with participants pre-allocated to these on the basis of their specialist knowledge.

- Group 1: Seabirds
- Group 2: Non-native species
- Group 3: Food webs
- Group 4: Extent of physical disturbance to seafloor/special habitats
- Group 5: Waterbirds
- Group 6: Inshore fish
- Group 7: Biogenic habitats (distribution/extent & condition) & intertidal seagrass
- Group 8: Deep-sea vulnerable marine habitats & deep-sea fish

Supported by a Facilitator and a Rapporteur, each group discussed some pre-set questions in turn and collated their views and responses. Each group finalised their agreed feedback, including group-level recommendations, which were then presented to all workshop participants in a plenary session. The full notes from each group have been captured in Appendix 4, with summaries of key recommendations from each group presented below (Sections 2.2 to 2.9).

2.2 Recommendations: Seabirds

The area of work supporting seabird indicators is highly policy relevant and the information is widely used. Seabirds have a good resonance with the public, and volunteers are vital to the collation of data. However, some data gaps remain, and interpretation of the indicator can be challenging as a result.

i. The SMA2020 and OSPAR seabird indicators use the same data but there are differences in data treatment (which are not well understood). Clarification is needed from those working with OSPAR assessments. Group members were content that both indicators fulfil a purpose and OSPAR results help to guide seabird assessment at the Scotland level. The two indicators are consistent, and a review was not recommended.

ii. Improve data availability for those species, species groups and survey locations that are currently under-represented (e.g. great skua, petrels, large gulls on the west coast and in urban areas), and make better links with diet studies for improved context. Additional sites with time series data are required to improve assessments at SMR scales.

iii. Improve data representativity through better co-ordinated volunteer effort, targeted to fill gaps in monitoring for some SMRs. Volunteer Seabirds at Sea (VSAS) surveys assist in gathering data for important seabird areas but at a relatively small scale. Surveys could be better targeted to provide improved data for certain areas and gather more opportunistic data from collaborative work with research vessels.

iv. Secure additional long-term resources for offshore surveys with bespoke monitoring. Compare seabird data with tracking studies to help to identify OMRs that are linked to breeding sites.

v. Make links with other survey data and indicators (e.g. for plankton) to help identify climate change effects. Census and count data could be used to identify shifts in species range, while breeding success would also help improve understanding of climate change effects. Monitor seabird wrecks, inundation of seabird colonies, and the spread of diseases or pathogens to provide additional contextual data. Assess the risk of flooding and sea-level rise to seabirds.

vi. Make better use of tracking studies (e.g. using geolocators) to fill the knowledge gap around seasonal changes in distribution of seabirds and wintering areas for seabirds that breed in Scotland.

vii. Fill gaps in assessment work, such as collating more contextual environmental data to support data interpretation; and making links with other relevant studies and indicators to support wider ecosystem assessments.

viii. Develop an understanding of how to use beached bird data, with better monitoring of wrecks and identification of their causes. The Dutch have collected this information for a number of years but clarity is needed on how results are used; should beached bird data be used for a Scottish indicator?

ix. Improve procedures for the detection, identification and mitigation of seabird disease epidemics (e.g. for future avian flu outbreaks).

2.3 Recommendations: Non-native species

All areas of development should be undertaken through the existing Scottish Marine INNS Group and the network of specialists associated with it.

i. A more detailed, formalised and co-ordinated monitoring programme is needed to better record and assess the spread of non-native species. Review monitoring tools and techniques, encouraging innovation in survey methods, data collation and data flows.

ii. Innovative sampling techniques such as eDNA could be used more widely to provide early warning alerts for new arrivals.

iii. More opportunistic non-native species data should be captured by public authorities during the course of other survey work, providing valuable early warning of new introductions.

iv. More records of non-native species abundance are needed (rather than presence/absence) including survey results with null report for non-native species.

v. Modelling could be developed to predict further spread of non-native species; identifying areas under pressure that should be targeted more frequently by future survey effort. Work should build on a study by MSS (Brown *et al*., in prep.) that will include analysis of hotspots for non-native species.

vi. Support research to investigate the impacts of non-native species on biodiversity, including effects on native species, food webs, local habitats and the wider ecosystem. This evidence is urgently needed in order to better understand the priorities for policy development and management decision-making.

vii. A better understanding of how individual non-native species (and their lifecycle stages) may react to climate change is needed.

viii. Recognise the role of citizen science and the need for it to be specific and focused in order to maximise its value as an additional data source. Give careful thought to how citizen scientist skills can be best applied and work with knowledgeable and interested local groups.

ix. Support citizen science with co-ordinated initiatives, tools and long-term funding to ensure that data are successfully captured and collated for wider use.

x. A full review of data flows is needed, with better co-ordination of data, from capture to storage and sharing, including more robust quality assurance throughout the data lifecycle. Future work should build on the findings of the data flows analysis undertaken by the Scottish Biodiversity Information Forum.

2.4 Recommendations: Food webs

The purpose of the food web indicator is to describe the collective status of associated species and assess the functioning of inter-relationships and the food web as a whole. It should support interpretation of changes in dynamics between species (e.g. predator-prey relationships), and interpretation of other marine biodiversity indicators. Bespoke food web indicators are not yet available but early developments are under way. Recommendations for development:

i. Develop more food web models based around different trophic levels to capture interspecific relationships, selecting examples with representative habitats and species that could be widely used. Increase the number of metrics and biological groups being considered.

ii. In developing food web models, connectivity (and dynamics) between trophic levels is important. This connectivity needs accurate information from nutrients as a baseline component, through primary producers and their primary consumers, to secondary consumers including seabirds and mammals. Understanding the seabird component of food web models is particularly important given their varied feeding types and functional roles.

iii. Prioritise the availability and reliability of input data, for example: include biomass estimation routinely in monitoring programs and increase accessibility to these data; develop more accurate conversion methods between species abundance and biomass data; gather more underpinning data on measurable life history traits (e.g. size of mussels), to provide greater context to modelled outputs.

iv. Identify and fill data gaps, such as: biomass data, dietary relationships and more time-series data. Sentinel monitoring sites (selected reference sites with long-term monitoring) would help to fill some of these.

v. Employ eDNA sampling techniques in sediment cores to assess how food webs have changed over time in a certain location (hindcasting).

vi. Collate data on human activities and pressures in case study areas in order to accurately interpret modelled outputs.

vii. Develop food web indicators at a scale appropriate to understand impacts of pressures on selected trophic groups. For example, different geographic scales need to be considered whether the focus is on phytoplankton-based models or those including highly migratory species such as marine mammals, fish and seabirds.

2.5 Recommendations: Extent of physical disturbance to seafloor/special habitats

i. Whilst new indicators may be needed to address specific concerns, it is vital to ensure the maintenance of existing indicators (and underlying datasets) with appropriate planning and resourcing in order to provide a long-term view of physical pressures.

ii. Improve the resolution of underlying data for indicator-based assessment with data more centrally managed, collated and readily accessible.

iii. Greater integration across indicators and datasets would improve the physical disturbance assessment output. However, challenges need to be addressed such as the differing scales at which indicators work. Other differences between indicators such as modelling assumptions and data gaps would also need to be addressed, to ensure confidence in results.

iv. Consider how ‘special habitats’ are defined in the wider sense for more comprehensive and meaningful assessments (i.e. which habitats are the most important (and sensitive) in the context of Scotland’s marine environment).

v. Make ‘special habitats’ more visible in physical disturbance assessments by undertaking more targeted surveys in order to improve underlying data (e.g. for OSPAR’s physical disturbance BH3 sensitivity layers).

vi. Improve the accessibility of data for activities and pressures and gather higher resolution (spatial and temporal) data to enable more precise mapping of activities. This will provide more accurate evaluation of spatial footprints across activities (and overlaps between them), supporting cumulative assessment of pressures and their impacts on seafloor ecosystems.

vii. Expand surveys beyond the assessment of abrasion pressure caused by fishing activities to include other local or regional activities causing physical disturbance to the seafloor (e.g. construction of marinas, boat moorings and offshore platforms).

viii. Gather higher resolution (spatial and temporal) fisheries data (e.g. Vessel Monitoring System (VMS) for larger vessels offshore or Remote Electronic Monitoring information for smaller vessels and inshore fisheries). Consider how to better determine the footprint of static fishing gear.

ix. Consider how developers could better define the footprint of their activities and make this information more widely available. Currently, this information is inferred from multiple sources such as the National Marine Plan Interactive (NMPI), Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs).

x. Assess cumulative impacts of multiple smaller or linear structures (such as cables and pipelines) as the cumulative footprint may be large or spatially concentrated. Consider the absolute footprint of activities in the context of the scale of the associated assessment unit, as this can influence perspective on the relative footprint size.

xi. Climate change effects, such as increased sedimentation from inflowing rivers or increased abrasion of sediments, are not well captured by current indicators. New or enhanced indicators may be needed. Future calculations on the severity of physical disturbance should include the impacts on blue carbon storage.

xii. Consider the potential for climate change and physical abrasion pressures to co-occur given the risk of enhanced cumulative impacts.

2.6 Recommendations: Waterbirds

Wintering waterbirds are an important feature but difficult to monitor. Designation of new marine SPAs potentially increases the need for more survey of waterbirds.

i. Aim to fill gaps in knowledge of trends in waterbirds at the SMR/OMR (as identified by SMA2020), including the need for more data for marine birds that are further from the coast, for example, associated with new marine SPAs.

ii. Climate change induced shifts could lead to birds moving to places where there is little or no monitoring, thus posing a risk to future understanding of these populations. Consider using data from other countries which are staging grounds for our wintering birds, as counts there are likely to provide some representation of trends in Scotland. Matching these with changes in Scotland's distribution would give a fuller picture.

iii. The proposed waterbird distribution indicator (led by JNCC/BTO) should help to reflect changes in distribution, including climate-induced changes. Consideration should be given to promoting this proposed indicator for adoption by OSPAR to give it more prominence.

iv. Careful consideration needs to be given to which species are included. For example, geese are doing relatively well, so their inclusion potentially skews results for the existing wintering waterbird indicator as geese are a terrestrial species.

v. Functional group reporting needs to be improved as these groups offer a more representative view of how the marine environment is used.

vi. Resolve the issue of shifting baselines, as raised in the UKMS. Consider selecting an arbitrary start point for waterbird monitoring and avoid picking a baseline that reflects a peak in counts.

vii. Implement more concurrent monitoring of other ecosystem components (such as plankton and seabed) to identify genuine large-scale oscillations in ecosystem status.

2.7 Recommendations: Inshore fish

i. A more holistic assessment of inshore fish is vital given their place in the food chain and importance for birds and marine mammals. Inshore fish surveys need to be more geographically comprehensive and have a higher sampling frequency (annual) to enable better understanding of population trends.

ii. A more structured approach to surveys is needed, based around an understanding of the functional value of inshore waters (and their habitats) for both resident and migratory fish. Fill data gaps to survey all essential habitats such as spawning grounds, capturing their whole lifecycle and ecology, especially for sensitive or priority species such as shad and sparling.

iii. More detailed data on species assemblages, status and trends is needed to better understand and manage the drivers of change.

iv. Review the recording of pressures including how data are assessed alongside species data. Pressures on inshore fish communities are varied and likely to increase with climate change.

v. Data on fishing effort in nearshore waters is a key gap (i.e. where boats are, how many, how often, and what they are catching). This would provide a better understanding of the distribution and intensity of fishing pressures including cumulative impacts.

vi. Employ more innovative technology and opportunistic survey methods, for example: satellite monitoring of fishing boats; tagging to increase understanding of species presence and movements; genetic sampling to better understand population structures and changes; and explore possibilities for eDNA and metabarcoding to enhance survey data.

vii. All survey data should be collated in one common and accessible repository to improve confidence in the inshore fish indicator and provide more robust results that can better inform future recovery plans and policy decisions.

2.8 Recommendations: Biogenic habitats (distribution/extent & condition) & intertidal seagrass

i. Fill gaps in the indicator suite for more comprehensive application and condition assessment at UK level (e.g. no loss of extent; quantifying level of physical damage).

ii. Improve monitoring of all activities and pressures affecting biogenic habitats to inform condition assessments and improve identification of potential restoration sites. Various issues need to be addressed (e.g. lack of data, poor data resolution, and (where modelling is used) appropriate ground-truthing).

iii. Develop and include an indicator for kelp, given its extent as a habitat and key role in ecosystem processes. Furthermore, collate and assess supporting data on pressures affecting extent and depth of kelp (e.g. harvesting and sedimentation).

iv. Undertake more research around the impacts from certain activities and pressures (e.g. cables, renewable developments, seaweed cultivation and fish farming). Furthermore, improve understanding and quantification of impacts from dispersed activities (especially fishing) and pressures (e.g. pollutants, eutrophication and smothering).

v. Implications of climate change for managing biogenic habitats are unclear, including spatial targeting of measures. Increase the number of repeated monitoring sites (and the frequency of repeated visits) to improve identification of short-term versus long-term changes and trends and understanding of key driving factors such as storm events.

vi. Undertake research to fill knowledge gaps relating to climate change effects, including: mobility of maerl in particular MPAs with increased storminess; ocean acidification effects on habitat viability; larval development and changes in habitat connectivity; links between human activities and climate change impacts, and potential cumulative effects.

vii. Measure long-term resilience of biogenic habitats via genetic structure and diversity, thus highlighting those habitats more sensitive to climate change.

viii. Increase monitoring for blue mussel beds to provide more evidence on the possible causes of recent declines, and potential solutions for their recovery.

ix. Integrate biogenic indicators with other data to improve the use of outputs for management. For example, differences in condition and recovery between managed and lesser managed areas; implications of activities and pressures; and other parameters (such as “reefiness”) to improve interpretation.

x. Use additional modelling and analyses to enhance information derived from surveys. Modelled recruitment and age structure provides additional details for habitat distribution and a greater understanding of extent. Functional trait analysis (derived from existing monitoring data) contributes to a better understanding of condition.

xi. Increase the use of new technologies to gather more data for biogenic habitats. For example, satellite mapping, surveillance drones and more data input to Seagrass Spotter would help collation of seagrass data at larger scales. DNA and/or eDNA collection via sediment and water samples could also be used to enhance survey data for seagrass and other features, using support from a collaborative network of rangers, semi-professionals and trained volunteers.

xii. Provide better co-ordination of other data sources to gather more data on presence, extent and condition, including from citizen science surveys and restoration sites. Comparison of pre- and post-restoration data is particularly useful in assessing recovery and informing future management.

xiii. Ensure smooth data flows and consistency in assessment and reporting through standardised data collation and recording (including metadata).

2.9 Recommendations: Deep-sea vulnerable marine habitats & deep-sea fish

i. Collaborative cross-sector work (academia, industry, government/public bodies) is needed to help address data gaps, share the cost of deep-sea surveys and research, and to ultimately provide the underlying datasets that will be used in indicator-based assessments for the deep sea.

ii. Robust assessment of deep-sea fish and benthic habitats relies on long term time-series information, necessitating a commitment to continue existing time series and a commitment to initiate new time series in priority locations.

iii. Deep-sea data need to be collected over long time periods (decades) because processes in the deep sea are typically slower than in shallower water. These environments need to be surveyed and monitored for longer periods to detect the impact of climate change and to establish suitable baselines against which to measure human-induced change.

iv. There needs to be effective communication around the clear policy need for long term time series information and how the information will be used by government bodies and/or policy customers.

v. Whilst deep-sea indicators need to have a clear link into supporting policy needs, they also need to be ecologically meaningful. For example, consideration could be given to an indicator approach for assessing changes in status and condition of elasmobranchs and the wider ecosystem in response to the bottom-trawling ban around 800 m depth.

vi. Data and information collated as part of ongoing OSPAR assessments for Threatened and Declining (T&D) habitats and species could be re-examined to extract data and information to support the assessment of Scottish deep-sea habitats. Previous work, such as that conducted by the H2020 ATLAS Project (Kazanidis *et al*. 2020), can help to inform decisions on how indicators could be improved for the deep sea.

vii. Indicators used in the Scottish Marine Assessment 2020 to assess shallow-water biogenic habitats and inshore fishes should be explored to see how these frameworks could be applied to deep-sea biogenic habitats and deep-sea fishes, where sufficient data are available. Some groups, such as deep-sea sharks, are not well assessed using existing indicators and require further consideration.

viii. Case studies based on deep-sea locations with more comprehensive data coverage should be used to trial and show-case new assessment approaches or indicators. This is particularly important as there is typically less information available for deep-sea fish and habitats compared to shallow-water environments, and it may not be possible or appropriate to apply shallow-water indicators to all deep-sea areas.

ix. The existence of biogeographic boundaries and depth-related trends should be considered when determining deep-sea assessment areas. For example, using pre-defined geographical assessment areas based on policy needs could impact the ability of indicators to effectively detect changes in the deep-sea fish community.

x. The methods used to calculate deep-sea indicators need to be able to account for the discovery of 'new' deep-sea habitat occurrences as exploration of the deep-sea environment continues. Otherwise, new habitat occurrences could artificially inflate the status or trends for these habitats.

xi. To move towards an ecosystem approach for deep-sea assessments, a greater number of species need to be assessed, particularly sensitive species, going beyond the biogenic habitats that are typically assessed.

xii. Additional indicators are needed to assess for connectivity in the deep sea, such as trophic connectivity (food webs) and genetic (population) connectivity. These connectivity indicators have clear links to policy, for example supporting assessments of MPA network connectivity and connectivity amongst Scotland's marine regions.

3 Collated Recommendations and Next Steps

3.1 Summary of recommendations

Group feedback was detailed with a wide variety of points raised across the eight groups. Despite this, similar themes emerged from the discussions and the key points and recommendations for each of these were summarised as follows.

Theme	Key points / Recommendations
1. The important role of indicators	Groups emphasised the value of indicators and the important role they play in decision-making for management and policy developments, including underpinning the aims and objectives for various marine strategies.
2. Clarify relationships between indicators, ensure integration and appropriate scale of application	Greater clarity is needed around the relationships between indicators (e.g. for different habitats) and how they should be integrated within assessments. This is important not just for highlighting interactions (e.g. food webs), but also in helping to interpret results for individual indicators and evaluate the wider picture of ecosystem health.
3. Further development of indicators	Some indicators need further development work to improve their accuracy and/or applications (e.g. for food webs, waterbirds and deep sea).
4. Need for supporting or contextual research	Additional research is needed to help interpret assessment results and provide context to outputs (e.g. prey, diet or tracking studies). This additional information would help to provide greater understanding of species interactions and pressures acting on the marine environment, thus enhancing the interpretation of indicator results, and providing more confidence in ensuing actions and policy developments.
5. Understanding climate change and ocean acidification	Bespoke work is needed to improve indicators (and underpinning biodiversity data) to better capture impacts of climate change and interpret the effects on species and habitats. Developments should focus on the causal drivers and mechanisms of climate change in particular.
6. Data collection	Identify data sources (e.g. existing long term monitoring programmes) and gaps. Additional long-term monitoring may need to be put in place to better support the accuracy and value of indicator results. Programmes should also be supported by formal and co-ordinated data partnerships to ensure long-term management, co-ordination between programmes and sustained finance. The value of data improves with standardisation, quality assessment, collation, careful management, and making it accessible to all.
7. Improved activity / pressure data	More supporting data on activities or pressures is needed, either for direct input to indicators, or to improve interpretation of results (e.g. a particular gap for inshore fishing).
8. Discoverability and access to data	Data flows need to be better managed with co-ordination of data, from capture to storage and sharing, including more robust quality assurance throughout the data lifecycle. Data are often stored across different platforms or databases, making it difficult to find and access all relevant data when using indicators.

Theme	Key points / Recommendations
9. Role of citizen science	Citizen science data already make an important contribution, but could enhance many of the indicators, though careful co-ordination and management is needed to gain best value. A range of aspirations were reported, from improving quality, identifying best use of citizen scientists, to increasing efforts with knowledgeable and interested groups.
10. Case studies	Focused case studies could be used to complement more formal indicator results to highlight localised issues (e.g. non-native species work in Orkney, or specific deep-sea locations that are particularly data-rich).

In addition, further suggestions were made in relation to the next steps of development, and in particular, grasping opportunities to ensure that progress is made. All opportunities to improve the effectiveness of data flows should be taken to ensure long-term data availability in support of indicators. Such developments will have resource implications, but it is vital that any resourcing barriers are overcome to ensure an effective supply of robust data to underpin marine biodiversity assessments. The Scottish Biodiversity Information Forum marine analysis should provide an agreed set of recommendations that will help to address data flow issues. There could also be opportunities to improve on specific data calls (e.g. via UKMS or OSPAR assessments).

Opportunities to develop and improve on indicators (and data flows) are often opportunistic, for example, tied in with requirements for assessment and reporting. However, there is also a long lead-in time to this work, with most indicators developed and refined following extensive research, ongoing assessment and review. As such, it is important that a process of continual improvement is followed, to ensure the correct information is available to respond to assessment, reporting and/or evidence requests when they arise.

3.2 Next steps

The workshop report will be published and shared specifically with marine science and policy specialists to inform the ongoing development of marine biodiversity indicators and support future assessment work. This includes Scotland's Seas Data and Assessment Group (SSDAG) where these recommendations will support consideration of the next steps for future assessments of the state of Scotland's seas. Beyond Scotland, the recommendations will also feed into future developments for monitoring and assessments under both the UKMS and OSPAR.

All attendees were thanked for their participation and contributions to the workshop. The Facilitators and Rapporteurs for breakout groups were gratefully acknowledged for their help in guiding discussions and capturing key points and recommendations. Group summaries made a substantial contribution to the content of this workshop report. All workshop participants had the opportunity to read the report before it was finalised and to provide clarifications or factual corrections where required.

Appendix 1: List of Workshop Participants

Joint Nature Conservation Committee
Holly Baigent – Marine Support Officer
Tim Dunn – Seabird Monitoring Manager
Alison Lee – Evidence and Operations Co-ordinator – Scotland
Stefano Marra – Senior Marine Assessment Scientist
Laura Pettit – Senior Marine Ecosystems Scientist
David Vaughan – Team Leader, ETC for Inland, Coastal & Marine Waters
Cristina Vina-Herbon – Joint Head Marine Ecosystems Team
Sofie Voerman – Applied Marine Ecologist
Ilka Win – Seabird Ecologist
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Neil Campbell – Fishery Advice Group Leader
Jim Drewery – Marine Survey and Fishing Technology Scientist
Dafne Eerkes-Medrano – Marine Biodiversity Science Advisor
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Katie Gillham – Head of Marine Ecosystems
Ben James – Marine Protected Areas Manager
David O'Brien – Biodiversity Evidence & Reporting Manager
Laura Steel – Marine Advisor: Benthic ecology
Glen Tyler – Marine Ornithology Adviser

Scottish Association for Marine Science
Mike Burrows – Marine Ecologist
Bhavani Narayanaswamy – Deep-Sea Ecologist & Microplastic Researcher

Scottish Environment Protection Agency
Marion Harrald – Senior Specialist Scientist: Marine Ecology
Janet Khan – Senior Specialist Scientist: Marine Ecology
Scot Mathieson – Principal Conservation Policy Officer

University of Edinburgh
Lea-Anne Henry – Marine Ecologist

Apologies were received from:
JNCC: Yessica Griffiths, Gemma Singleton, Beth Stoker & Karen Webb
Marine Scotland: Adam Cox
Marine Scotland Science: Eileen Bresnan
NatureScot: Tracey Begg, Suz Henderson, Lisa Kamphausen & Emma Philip
University of Edinburgh: Murray Roberts

Appendix 2: Workshop Programme

NatureScot / JNCC / MSS Workshop to Review the Suite of Marine Biodiversity Indicators for Scotland's Seas

Held online, Thursday 3rd March 2022

Session 1 – Introduction and Scene Setting

09:30-09:35 Welcome (Alison Lee, Evidence & Operations Co-ordinator – Scotland, JNCC)

09:35-09:45 Outcomes of Scotland's Marine Assessment 2020 and the gaps/lessons learned in respect of biodiversity indicators
(Katie Gillham, Head of Marine Ecosystems, NatureScot)

09:45-09:55 Marine biodiversity indicators in the wider context
(Cristina Herbon, Marine Ecosystems Co-Team Lead, JNCC)

09:55-10:05 Plan for the day and expected outcomes
(Rachel Boschen-Rose, Benthic Ecologist, MSS)

- Breakout Groups – ways of working, key questions to consider, collating views and preparing feedback for the final recommendations.

10:05-10:15 Questions and clarifications (all)

Session 2 – Breakout Groups (1)

10:15-11:50 Discussion in Breakout Groups – *including a 10-minute break*

- 1: Seabirds
- 2: Non-native species
- 3: Food webs
- 4: Extent of physical disturbance to seafloor/special habitats

11:50-12:30 Group feedback session in plenary (Katie Gillham, NatureScot)

Session 3 – Breakout Groups (2)

13:40-13:45 Brief introduction to Breakout Group session 2 (Alison Lee, JNCC)

13:45-15:10 Discussion in Breakout Groups

- 5: Waterbirds
- 6: Inshore fish
- 7: Biogenic habitats (distribution/extent & condition) & intertidal seagrass
- 8: Deep-sea vulnerable marine habitats & deep-sea fish

15:10-15:20 Afternoon break

Session 4 – Group Feedback & Collating Recommendations

15:20-16:00 Group feedback session in plenary (Katie Gillham, NatureScot)

16:00-16:20 Collating final recommendations (Katie Gillham, NatureScot)

16:20-16:30 Concluding remarks and next steps (Alison Lee, JNCC)

Appendix 3: Summary of Marine Biodiversity Indicators Relevant to Scotland's Seas

Abbreviations used in the table:

- OSPAR IA: OSPAR Intermediate Assessment 2017
- UKMS/MOAT: UK Marine Strategy/Marine Online Assessment Tool 2019
- SMA2020: Scotland's Marine Assessment 2020
- SBS: Scottish Biodiversity Strategy
- NPF: National Performance Framework

Indicator names given in italics (and suffixed with †) are those that contribute to the food webs assessment under the relevant assessment process. For example, under the UK Marine Strategy work, the top three marine bird indicators all contribute to that food web assessment; and under the OSPAR Intermediate Assessment, all of the fish indicators contribute to that food web assessment.

Key to table:

- Shaded (and suffixed with #): categories that were the subject of specific Breakout Group discussions at the workshop.
- Text in bold (and suffixed with *): the specific indicators that were the focus for discussions in the Breakout Groups.
- Text in [ ]: case studies that were included as part of SMA2020, some of which were considered alongside the indicators at the workshop.

Category	OSPAR IA	UKMS/MOAT	SMA2020	Scottish Indicators
Birds #	• **Marine bird abundance** * • **Marine bird breeding success/failure** *	• ***Marine bird abundance*** †* • ***Marine bird breeding success/failure*** †* • ***Kittiwake breeding success*** †* • Invasive mammal presence on island seabird colonies • **(Pilot assessment of) distribution of breeding and non-breeding marine birds** *	• ***Abundance of wintering waterbirds*** †* • ***Seabirds (abundance and breeding success)*** †*	• **Wintering Waterbirds (SBS)** * • **Seabirds (SBS)** * • Biodiversity – the marine component comprises the abundance part of the seabird indicator (NPF)
Deep Sea #			• ***Deep-sea fish*** †* • **[Deep sea Vulnerable Marine Ecosystems]**	

Category	OSPAR IA	UKMS/MOAT	SMA2020	Scottish Indicators
Fish (including shellfish) #	• *Size composition in fish communities* † • *Recovery in the population abundance of sensitive fish species* † • *Proportion of large fish* † • *(Pilot assessment of) mean maximum length of fish* †	• *Size composition in fish communities* † • Recovery in the population abundance of sensitive fish species • *Proportion of large fish* † • *Species composition in fish communities* †	• Commercial fish • ***Inshore fish (estuaries and reduced salinity sea lochs)*** †* • Salmon and sea trout • *Wider fish community* † • Commercial shellfish	• Sustainability of fish stocks (NPF)
Food webs #	The **indicators** under this section related either to plankton or fish, and have been listed under those categories instead *(shown in italics)*. There is no separate assessment for food webs.	This **assessment** was based on a summary interpretation of targets and indicators used to assess progress. *Shown in italics.*	**[Case study]** (rather than a full assessment/indicator). Adopted similar approach to UKMS, i.e. a narrative summarising results of other assessments. *Contributing assessments shown in italics.*	N/A

Category	OSPAR IA	UKMS/MOAT	SMA2020	Scottish Indicators
Habitats #	• **Extent of physical damage to predominant and special habitats** * • Condition of benthic habitat defining communities	• **Condition of intertidal seagrass communities in coastal waters determined using WFD methods** * • Condition of intertidal saltmarsh communities in coastal waters determined using WFD methods • Condition of intertidal rocky shore macroalgae communities in coastal waters determined using WFD methods • Condition of benthic communities: subtidal habitats of the Southern North Sea • **Extent of physical damage to predominant seafloor habitats** * • Condition of soft sediment invertebrate communities in coastal waters using WFD methods • Potential physical loss of predicted seafloor habitats	• **Intertidal seagrass** * • **Predicted extent of physical disturbance to seafloor** * • **Biogenic habitats** *	N/A

Category	OSPAR IA	UKMS/MOAT	SMA2020	Scottish Indicators
Mammals	• Seal abundance and distribution • Grey seal pup production • Harbour porpoise bycatch • Abundance and distribution of coastal bottlenose dolphins • Abundance and distribution of cetaceans • (Pilot assessment of) abundance and distribution of killer whales	• *Changes in the abundance and distribution of seals* † • *Grey seal pup production* † • Harbour porpoise bycatch • *Abundance and distribution of coastal bottlenose dolphins* † • *Abundance and distribution of cetaceans other than coastal bottlenose dolphins* †	• *Seals (abundance and pup production)* † • *Cetaceans (harbour porpoise, white-beaked dolphin, killer whale, bottlenose dolphin)* †	N/A
MPAs	• Status of the OSPAR network of MPAs	• Progress towards an ecologically coherent and well-managed network of MPAs in the UK	• Marine Protected Areas	Condition of protected nature sites (mix of terrestrial and marine) (NPF)
Plankton	• Changes in phytoplankton and zooplankton communities (counted under 'habitats' by OSPAR) • Changes in phytoplankton biomass and zooplankton abundance • (Pilot assessment of) changes in plankton diversity • *(Pilot assessment of) production of phytoplankton* †	• Changes in plankton biomass and abundance • Changes in plankton communities	*Plankton (changes in life from abundance)* †	N/A

Category	OSPAR IA	UKMS/MOAT	SMA2020	Scottish Indicators
Non-native species #	• **Trends in new records of non-indigenous species introduced by human activities ***	• **Trends in newly recorded non-indigenous species introduced by human activities ***	• **Non-native species *** • **[Marine non-native species monitoring in the Orkney Islands]**	N/A

Note that SMA2020 includes a series of case studies relating to different habitats and species. Those considered to be most relevant to the Breakout Groups were listed in square brackets in the table above. The table below lists other case studies with some links to the workshop discussions.

SMA2020 Case Studies: Habitats	***SMA2020 Case Studies: Species***
Biogenic habitat enhancement Persistent damage to the Loch Creran serpulid reefs Protecting the Loch Carron flame shell beds Seabed habitats in territorial waters – the evolving knowledge base	Carpet sea squirt Sandeels in Scottish waters

Appendix 4: Rapporteur Notes from Breakout Groups

Rapporteur Notes from Group 1 – Seabirds

Group Facilitator: Glen Tyler (NatureScot); Rapporteur: Simon Foster (NatureScot)

Question 1: There are different methods used, e.g. for the SMA2020 and OSPAR indicators. Is there a need for consistency/review?

- Differences in data treatment with OSPAR and SMA2020 are not well understood – some clarification is required from those who work with OSPAR. Although there are differences between the OSPAR indicator and Scotland's national indicator they use the same data, and Group members were content that both fulfil a purpose. OSPAR results are used in helping guide understanding at a Scotland level. In summary, the two indicators are consistent and complementary, and a review was not recommended. However, an improved understanding of OSPAR would be useful.

Question 2: SMA2020 identified the following gaps in our knowledge of seabirds. How could these be addressed or is there work already underway to address them?

2a) Trends in seabirds at the SMR/OMR scale.

- Improved volunteer resource is needed with better co-ordination of effort, targeted to fill gaps in monitoring. A monitoring strategy review will focus this effort and help to identify the SMR areas that require more robust monitoring. Comparison with tracking studies will help to identify OMRs that are linked to breeding sites. Volunteer Seabirds at Sea (VSAS) surveys assist in gathering data for important seabird areas but at a relatively small scale. These surveys could be better targeted to provide improved data for certain areas. Collaborative work with research vessels could also provide more opportunistic data. Additional offshore monitoring with bespoke surveys may also provide useful data but no resource has been identified and surveys would be costly and challenging to fund in the long-term.

2b) The implications of climate change.

- The indicator does not currently assess climate change impacts directly. Key site monitoring provides data on diet which could be used to infer climate change impacts on the food chain. Making links with other survey data and indicators (e.g. plankton) was recommended to help identify climate change effects. Census and count data could be used to identify any shifts in species range, while breeding success would also help improve understanding of climate change effects. Other species data (e.g. petrels, puffins) may also provide information. Monitoring seabird wrecks, inundation of seabird colonies, and diseases/pathogens would also provide additional contextual data.

2c) Seasonal changes in the distribution of seabirds – including lack of knowledge of key wintering areas for seabirds that breed in Scotland.

- This is a rapidly developing area of study and tracking studies (e.g. geolocators) are helping to fill the knowledge gap. VSAS surveys operate throughout the year and may provide some data although there is a time-lag in gathering a dataset that could be analysed to accurately detect seasonal changes in distribution. Bespoke surveys would provide more accurate data and information, but resourcing constraints are an issue.

Question 3: Are there any other key gaps that need to be addressed to support assessment work?

- Availability of data availability is declining due to resourcing and logistical challenges. Census data are required to improve estimates, but more sites are needed to improve assessments at SMR scales. Currently, some species groups and survey locations under-represented, e.g. petrels, large gulls on the west coast and urban areas. No trend information is available for great skua. Making better links with diet studies would improve data availability.

- The bird flu outbreak highlighted a risk in our ability to undertake rapid response and assessments for seabirds. Better co-ordination is required.

- The risk of flooding and sea level rise to seabirds.

- A possible gap for future: understanding how to use beached bird data, identifying wrecks and their causes. The Dutch have collected this information for a number of years but clarity on how they use the results would be needed, should the data be incorporated into an indicator.

Question 4: What are the key lessons learned from seabird indicator work to date?

- The seabird indicator is highly policy relevant, and the information is widely used. The indicator has a good public resonance and volunteers are vital to its production. Data gaps and interpretation can be challenging.

Question 5: What are the priorities for work on seabird indicators to improve future assessments?

- Seabird Monitoring Programme Sampling Strategy work.
- Environmental monitoring to provide context to changes in status and trends.
- Addressing the knowledge gaps as identified.
- Ecosystem assessments – linking with other relevant studies and indicators.

Rapporteur Notes from Group 2 – Non-native species

Group Facilitator: Katie Gillham (NatureScot); Rapporteur: Alison Lee (JNCC)

Question 1: SMA2020 identified the presence and location of non-native species and how quickly they are spreading as key knowledge gaps. What should be done to address these in terms of:

1a) Monitoring and surveillance, including through citizen science?

- Non-native species data principally consist of presence/absence records and tend to be sparse or ad hoc in nature, with low confidence due to unverified records. Consequently, it is often difficult to be certain when a species first arrived at a particular location and information on their subsequent spread may be unclear. A more detailed, formalised and co-ordinated monitoring programme is needed to better record and assess the spread of non-native species.

- Early warning and prevention of non-native species are key to tackling their spread and impacts. Innovative sampling techniques such as eDNA could be used more widely to provide alerts for new arrivals.

- Clear evidence of the impacts on biodiversity (native species and habitats) is often lacking, yet reporting such pressures forms an important element of OSPAR assessments. Research is needed to better understand these impacts, and any recommendations for new or enhanced survey techniques must be integrated within survey designs.

- Modelling work to help predict the spread of some non-native species has been undertaken by the Scottish Marine INNS Group, e.g. *Sargassum muticum* for which data was derived from ad hoc surveys and citizen science. Further models could be developed to support monitoring programmes, by identifying pathways and hotspots to focus future survey effort.

- MSS carried out hotspot analysis for introduction and spread of non-native species, considering the main introductory pathways. The report (Brown et al., in prep.) will include this hotspot analysis and can be used as a basis to advise monitoring programme design. The group also recommended the need for another workshop in 2022 to build upon this work in order to identify the most important pathways and hotspots for non-native species introductions and spread. These areas should be targeted more frequently by monitoring programmes.

- Citizen science was discussed, and its value was recognised when targeted in specific locations or for particular species. Data capture and accuracy could be enhanced by approaching knowledgeable and interested groups, for example divers or boat users, depending upon location. Accurate records rely upon co-ordinated survey effort, including quality assurance and central recording, so investment in these aspects was recommended. In summary, a more co-ordinated monitoring programme for non-native species is needed, with relevant bodies working together, supported by citizen science as appropriate.

1b) Making better use of existing non-native species data?

- Non-native species data have been collated and stored in various formats by different organisations with no central data repository. Consequently, when compiling data for non-native species reporting, responsible authorities rely on requests to multiple organisations. This process is inefficient and likely to include data gaps and errors. A full review of data flows is needed, with better co-ordination of data, from capture to storage and sharing, including more robust quality assurance throughout the data lifecycle.

- Some work is already under way to review non-native species data flows, for example via the marine Scottish Biodiversity Information Forum (SBIF) analysis (due for completion shortly). Future work must build on these findings.

- The citizen science reporting portal for non-native species on Scotland's Environment Web is not widely used and confidence in the data is uncertain. Some targeted citizen science activity has been more successful, especially when part of a structured initiative that is supported by tools and funding, e.g. the Seasearch programme or Sealife Tracker app. Ongoing support of such initiatives is vital to ensure that data are successfully captured and collated for wider use.

- Careful thought should be given to how citizen scientist skills can be best applied, e.g. for species that are simple to identify, or in straightforward tasks (such as collecting water samples for further eDNA analysis by specialists), or in taking photos for automated identification and verification.

Question 2: Are there any lessons learned from NNS assessment work to date?

- Data records principally consist of species presence/absence (rather than abundance). As such it has been difficult to derive trends on changes in distribution and abundance, especially as 'species absence' may reflect a lack of survey effort rather than true absence. A more detailed and co-ordinated monitoring programme, together with improved data management, would help to address this.

- Public authorities should assess opportunities that already exist during the course of other survey work to look out for and record any non-native species. Opportunistic records such as these could provide valuable early warnings for new introductions.

- More species-specific knowledge is needed to assess the full extent of impacts. Currently, the full extent of negative impacts is not well understood for some non-natives, which may include pressures in the food chain, food web imbalances and major ecosystem changes. This evidence is urgently needed in order to better understand the priorities for policy development and management decision-making.

Question 3: Are there specific issues in relation to climate change to support future assessment of NNS?

- The spread of non-native species is closely linked with climate change (for example, warming waters), but crucially effects vary by species. A better understanding of how individual species (and their lifecycle stages) may react to climate change is needed. Carpet sea squirt *(Didemnum vexillum)* and Pacific oyster *(Crassostrea gigas)* were discussed as examples.

- A separate but related issue is the potential for new or enhanced introduction pathways under climate change scenarios. A broad range of temperate water species from the western Pacific have become established in the Atlantic, which over time has altered the spectrum of species established in Scottish waters. Introduction pathways have been a key driver for spread, and climate change effects may accelerate these leading to increased prevalence of non-native species. An assessment of risks related to climate change effects was recommended, especially changes in non-native species distribution and abundance.

Question 4: What are the priorities for work on NNS to improve future assessments?

All areas of development should be undertaken through the existing Scottish Marine INNS Group and the network of specialists associated with it, including:

- Support research to investigate the impacts of non-native species, in terms of effects on native species, food webs, local habitats and the wider ecosystem.

- Assess risks associated with climate change effects, especially changes in non-native species distribution and abundance.

- Review non-native species monitoring tools and techniques, encouraging innovation in survey methods, data collation and data flows.

- Recognise the role of citizen science and the need for it to be specific and focused in order to maximise its value as an additional data source.

Rapporteur Notes from Group 3 – Food webs

Group Facilitator: David Vaughan (JNCC); Rapporteur: Holly Baigent (JNCC)

Question 1: Have there been enough new developments (e.g. in OSPAR, MSFD, SMA) to point to a way forward? Identify directions for travel, as well as actions, where should resources go?

- Development is underway at OSPAR level (Quality Status Report 2023) on an indicator called the "*Ecological Network Analysis Indices (FW9) indicator".* Led by Germany, the work is being developed by a food web expert group, who are creating a pilot assessment based on relationships between different trophic levels.

- JNCC is exploring development of a benthic ecotrophic model based around a study area in the southern North Sea. An attempt last year failed to balance. This static food web-based method uses an ecopath model looking at trophic relationships using a mass-balanced snapshot. Other food web tools can be used to explore temporal variation (ecosim) or spatial-temporal variations (ecospace).

Question 2: The case study in SMA2020 shows the potential components that are available currently for different biological groups. Should the emphasis for future work be on:

- *Increasing the number of metrics and biological groups being considered?*
- *Increasing the availability of models for assessing trophic relationships?*
- *Focusing more on other ecosystem concepts such as energy flows?*

The group considered the first point (metrics and biological groups) and noted:

- Effort to integrate metrics is important as a first step towards building models.
- Abundance is commonly used, e.g. in Marine Recorder.
- Ecopath used biomass but data (especially for benthic species) were difficult to obtain.
- Confidence and reliability of data for food web parameters should be prioritised.
- The purpose of the food web indicator is to describe the collective status of associated species and assess the functioning of inter-relationships and the ecosystem web as a whole. It should support interpretation of changes in dynamics between species, e.g. predator-prey relationships, and interpretation of other marine biodiversity indicators.

Question 3: Are there any other key gaps that need to be addressed to make food web indicators viable?

- Currently food web indicators appear to be a collection of separate indicators focused on different trophic levels, rather than one holistic indicator encompassing different species and dynamic interactions. As such they fail to capture interspecific relationships.

- The group considered food webs examples to help focus initial development, e.g. plankton, sand eels and seabirds. Representative habitats and species could be another place to start, e.g. kelp due to its base as a nursery habitat and for food provision.

- Data gaps were identified, e.g. biomass data, dietary relationships and time-series data. Sentinel monitoring sites (selected reference sites with long-term monitoring) would help to fill some of these.

Question 4: What are the key lessons learned from food web work to date?

- Nutrients form an important baseline component within food webs. Seabirds should be included given their place in the food chain, varied feeding types and functional groups. Connectivity (and dynamics) between trophic levels is also important.

- Accurate estimation of human activities in case study areas is important to enable accurate interpretation of outputs.

Question 5: What are the priorities for work on food web indicators to improve future assessments?

- Develop accurate conversion methods between species abundance and biomass data.

- Include biomass estimation routinely in monitoring programs and increase accessibility to these data.

- Develop more food web models based around different trophic levels, selecting examples with representative habitats and species that could be widely used.

- Gather more underpinning data on measurable life history traits, e.g. size of mussels, to provide greater context to modelled outputs.

- Employ eDNA sampling techniques in sediment cores to assess how food webs have changed over time in a certain location.

Question 6: How can food web models relate to legislation?

- All can be used to assess the state and stability of marine ecosystems, and impacts from pressures. All contribute to management and development of future legislation and policy.

- Can help predict future trends for different components (forecasting).

Question 7: What scale should food webs indicators be developed at? Is it more realistic to restrict geographical scale?

- This depends on the selected trophic groups or agents in the model. A local-scale model would not be appropriate for highly migratory species such as marine mammals, fish and seabirds. Phytoplankton-based models could be developed at a regional scale.

- Changes in temperature can alter species distribution and food web operation (Serpetti *et al.* 2017), and a regional-based assessment would capture impacts relating to climate change assessment.

Reference: Serpetti, N., Baudron, A.R., Burrows, M.T. *et al.* (2017) Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach to Fisheries. *Sci Rep* **7,** 13438 (2017). https://doi.org/10.1038/s41598-017-13220-7

Rapporteur Notes from Group 4 – Extent of physical disturbance to seafloor/special habitats

Group Facilitator: Cristina Vina-Herbon (JNCC); Rapporteur: Rachel Boschen-Rose (MSS)

Overall key messages from the group:

1. Whilst new indicators may be needed to address specific concerns, maintenance of existing indicators and keeping underlying datasets up to date is also important. Resource planning for indicator work needs to ensure that appropriate resources are maintained following the initial push on indicator development and data provision.

2. Higher resolution (spatial and temporal) and improved accessibility of data for activities and pressures are needed to ensure activities can be mapped with greater precision. This supports more accurate evaluation of spatial footprints and assessment of footprint overlap amongst activities, supporting cumulative assessment of pressures and their impacts on seafloor ecosystems.

Question 1: Are there any local or regional anthropogenic pressures or activities causing physical damage which should be added or included under the method of existing indicators?

Key summary points:

- The assessment of physical disturbance to the seafloor should include activities that are more frequent in Scotland. The historical focus on abrasion pressure from fishing needs to be broadened to encompass other local or regional activities causing physical damage in Scottish waters.

- To provide robust assessments on the physical disturbance from fisheries, there needs to be higher resolution (spatial and temporal) fisheries data, including Vessel Monitoring System (VMS) information, or similar, for smaller vessels and inshore fisheries. Consideration is also needed of how to determine the footprint of static gear. Ultimately fisheries data need to be ground-truthed, as pressure assessments can only proceed so far based on models and metrics.

- Consideration should be given as to how developers could better define the footprint of their activities and make this information more widely available. Currently, this information is inferred from multiple sources, such as the National Marine Plan Interactive (NMPI), Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs).

- The absolute footprint of activities needs to be considered in the context of the scale of the assessment units, as this can change the perspective of the relative footprint. For example, construction in Scottish inshore regions, smaller regions or sub-regions will have a relatively larger footprint than a similar activity occurring within a bigger marine region.

- The cumulative impact of multiple smaller structures, such as cables and pipelines, needs to be considered as the cumulative footprint for these could be large and spatially concentrated in localised areas or regions.

Additional points for question 1:

- Temporary pressure-causing activities, such as construction, are not captured by current assessments of physical disturbance. Consideration should be given to how disturbances occurring for less than one year could be assessed.

- Consideration is needed on how to capture hydrographical change, for example where wind turbines are placed and provide new hard substrate. Currently, this pressure would be assessed as loss of soft substrate habitat.

- Work is ongoing to extend the OSPAR indicator assessment of physical disturbance (abrasion) from fisheries to aggregate extraction, but this is a less common activity in Scotland. More common activities to be considered in future are large construction projects such as new marinas and offshore platforms and smaller activities such as boat moorings.

- Consideration should be given as to how data collection can be ‘future-proofed’ to make sure the underlying datasets continue to be appropriate for indicator-based assessments and that multiple pressure-causing activities can be assessed with these datasets.

- More joined-up and appropriately resourced approaches are needed to pull together all the publicly available information held by different organisations to determine accurate footprints for Scotland’s marine industries. Assessing the actual footprint of new wind farms is challenging as leases have only recently been issued, although the overall lease areas could give a conservative view of the potential future spatial extent. Different levels of detail are available from different data sources, for example, NMPI may indicate the location of a cable corridor but the EIA would be needed to see exactly where the cable is buried. NMPI also includes information on ports and harbours.

- It was noted that in Scotland’s Offshore Marine Regions (OMRs), the fisheries footprint is typically an order of magnitude larger than that of any other activity.

- Regional data calls could be issued for Scotland as a whole, or specific marine regions, without having to go through OSPAR or ICES to obtain data. Targeted additional data collection should be considered at appropriate (regional) scales so that information is not lost at larger spatial resolution.

Question 2: Are there any local or regional climatic drivers which should be added or included under the method of existing indicators?

Key summary points:

- Impacts caused by climate change drivers are different from activities causing physical abrasion, in that climate change has a wider scope and is not focused on a specific activity. The potential for climate change and physical abrasion pressures to co-occur as cumulative impacts warrants further consideration.

- The underlying biogenic habitat layers, including habitat extent and distribution, used to assess physical abrasion pressure may change as a result of climate change. Currently there is no mechanism to ensure the biogenic layer tracks changes due to climate pressures and to ensure any necessary updates are made.

- River inputs to coastal systems, such as increased sedimentation, are not captured well by current indicators. These inputs could change due to climate pressures and change the physical characteristics of the seafloor, altering the effects of abrasion. Such changes may be beyond the ability of current indicators to address.

- Current indicators do not consider, for example, the ability of sediments to store carbon. Future calculations for the level of disturbance should include the impacts on blue carbon storage. Abrasion pressure has the potential to release blue carbon stored in the sediments, thus decreasing the health of sediment habitats and increasing ocean acidification in wider habitats.

Additional points for question 2:

- Existing climate change model projections could be scaled across Scotland waters, although model resolution may not match the scale of interest. Model projections may need to be adapted so they are more applicable and can be used as metrics in the indicator calculations. Additional parameters linked to climate change should be considered, such as increased storminess or wind speed, which could increase scouring of the seabed.

- Most of the oceanographic layers providing information on parameters linked to climate change are at a broad scale. More localised models are needed for these layers to be able to incorporate finer scale climate change in pressure assessments. Sensitivity layers capturing climatic sensitivities at suitable scales could feed into assessment of the BH3 indicator.

- Climate change needs to be addressed not only for lightly impacted areas but also for areas that are heavily impacted and where there are existing activities. In the current spatial layer used to assess the impacts of fishing, some areas are already heavily modified in terms of the species present due to existing or prior pressures, which needs to be taken into account in the context of climate change. In some areas species may have already lost resilience due to climate change but these areas still need to be considered.

- Ecologically relevant pressure thresholds for physical disturbance are often lacking for the species or habitats that policy is seeking protect.

- In general, the near coast is not well-captured in climate change models or physical disturbance pressure assessment.

Question 3: Are there any special habitats which should be included in the assessments?

Key summary points:

- Further consideration needs to be given to how ‘special habitats’ are defined. For assessments to be as comprehensive and meaningful as possible, the definition of ‘special habitats’ should take into account what is important in terms of Scottish marine biodiversity and the sensitivity of marine habitats to the different pressures occurring in the Scottish marine environment.

- In general, there is a need to make special habitats more visible in physical disturbance assessments. Physical disturbance BH3 sensitivity layers already include threatened and declining habitats, and if biotopes have been mapped, sensitivity assessments can be conducted for these biotopes. If there is a policy need for more information about special habitats then the underlying data layer will need to be improved, which may require additional targeted survey effort.

Additional points for question 3:

- The size of the habitat and its distribution need to be considered when assessing physical disturbance. For example, Serpulid reefs occur as small habitat patches and may need different assessment approaches or indicator calculations. Different assessments or indicators may be needed for different habitat spatial scales or distribution patterns.

- Some habitats may be under pressure from very localised activities with small spatial footprints. These activities are on a much smaller scale than fishing, for example, but could have a disproportionate effect on small, localised habitat patches or habitats with a restricted distribution. Indicator-based assessments could consider stratification by habitat to help address this.

- Additional effort may be needed to adequately capture and assess 'special' habitats that stand out when doing the standard physical disturbance calculations. These habitats could be considered to not be representative of the wider area and may require a modified assessment approach or their own specific indicator.

- Consideration is needed on how to better apply the BH3 physical disturbance indicator and biogenic indicator to the deep sea, as these indicators were both developed for near shore or shelf habitats.

- Special habitats have particular meaning under the Marine Strategy but in the wider context could be any habitats that are particularly sensitive to the pressures of interest. Special habitats could also be a relative term, for example, are habitats considered special if they occur where more people can access them?

- Looking to the deep sea, candidate special habitats could include carbonate mounds, deep-sea coral reefs, sponge grounds and burrowed muds, for example. Overlap with the existing biogenic indicator needs further consideration; different indicators do not always mesh well as they are designed to measure different aspects of the environment or specific habitats.

- Potential shallow-water 'special habitats' include *Sabellaria spinulosa* reef and Kelp, both of which are threatened and declining habitats. Kelp may warrant its own indicator to monitor declines resulting from human activity climate change pressures.

Question 4: Should Extent of physical damage indicator be integrated with other indicators or data to improve the use of the outputs for management perspective?

Key summary point:

- Greater integration across indicators and datasets would improve the physical disturbance assessment output available to environmental managers. However, there are multiple challenges for such an approach, including the differing scales that indicators work at, and how to address the gaps and assumptions of high-level models.

Additional points for question 4:

- Different spatial scales may be appropriate for assessing different pressures, according to the spatial extent of the activity. For example, the C-square metric for BH3 operates at a wide scale, to match the extent of fishing activity, but it is subsequently spatially coarse. Applying a similar coarse resolution to smaller-scale activities, such as fixed installations and construction, can considerably inflate their footprint.

- Opportunities for integration include combining some of the results from assessing the extent of physical damage to biogenic reefs with the status of biogenic reefs.

- How loss of habitat is reported could be improved, in particular quantifying the footprint that leads to loss instead of just abrasion pressure. For example, in construction pilings are habitat loss and not physical disturbance. Loss could mean either permanent removal of the habitat or no recovery of the original habitat.

- Ground-truthing is an important part of the integration of indicators and datasets. High-level models for physical disturbance typically have large data gaps and assumptions. Some of these gaps and assumptions could potentially be addressed through using specific condition indicators or establishing real-life thresholds for pressures that lead to certain measured impacts. Integrating this additional information could help improve higher-level physical disturbance models.

Question 5: What are the key lessons learned from benthic indicator work to date?

Key summary points:

- The resolution of underlying data is not always appropriate for indicator-based assessment. In some cases, poor data resolution may represent a real absence in high resolution data, in others the data may exist but they are not publicly available or readily accessible.

- The provision of higher resolution activity and pressure data, for example for fishing activity, would enable a more accurate evaluation of where activities are occurring. In real terms, this could reduce the calculated footprint of an activity and potentially place the industry in a more favourable light in terms of its spatial extent. Such an approach would enable more robust comparisons of spatial footprint between industries and support cumulative assessments.

- Resources need to be planned for the maintenance of indicators and underlying data, in order to provide the long-term view of physical pressures.

- Standardisation amongst indicators and assessment methods would be needed to make linkages between assessments and the application of different indicators.

Additional points for question 5:

- To aid the interpretation of assessment outputs, consideration needs to be given to alternative ways to presenting summary metrics. For example, displaying actual footprint instead of iconography for maps. Some activities, particularly those with a smaller footprint, would benefit from better representation of their spatial footprint. Future assessments should include a better breakdown of the data products within regions, to help provide a more detailed picture of variation within regions.

- Some marine regions could be better stratified to enable pressures to be assessed at the appropriate spatial scale. For example, to address overrepresentation of abrasion in certain habitats or future consideration of wellbeing near coastal areas.

- Better links are needed between assessment processes to feedback and incorporate improvements in the application of indicators at different spatial scales. Such an approach would support efforts for standardisation and help to conserve resources.

- When calculating the resources needed for assessments, consideration needs to be given to supporting appropriate analysis methods for (potentially large) dataset calculations.

Rapporteur Notes from Group 5 – Waterbirds

Group Facilitator: Katie Gillham (NatureScot); Rapporteur: David Vaughan (JNCC)

Question 1: SMA2020 identified a gap in our knowledge of trends in waterbirds at the SMR/OMR scale – how could this be addressed?

- WeBS data is focussed on shore birds and is not ideal for marine birds that are further from the coast, e.g. sea-ducks.

- There will continue to be a wintering waterbird indicator, based on WeBS data that covers marine and freshwater. In terms of developing the SMA2020 waterbirds indicators, NatureScot is pursuing discussions with BTO to develop a marine-only indicator, as the current wintering waterbird indicator includes non-marine areas and also includes more terrestrial waders such as bar-tailed godwit.

- There is lower confidence in the data for non-estuarine waders as surveys are infrequent. However, designation of new marine SPAs potentially increases the need for survey. (Tim Dunn (JNCC) updated the group about parallel work being developed in England.)

- Unmanned aerial vehicles (UAVs) are being trialled to collect data on marine birds.

- Volunteers already collect a lot of marine waterbird data. BTO has the largest volunteer network and the infrastructure to manage that. We should encourage new volunteers to join with current BTO schemes for maximum effect, as volunteers make a significant contribution to our monitoring. There is a need to encourage more young people to get involved.

- A combination of citizen science and professional survey will continue to be needed in order to meet data requirements.

- Need to ensure correct survey coverage, e.g. long-tailed ducks are under-sampled in inshore waters (as are scoters). No trend data are available for long-tailed duck in Scotland, even though the species is part of new SPAs.

- Consider using data from other countries which are staging grounds for our wintering birds, as counts there are likely to provide some representation of trends in Scotland. Matching these with changes in distribution in Scotland would give a fuller picture.

Question 2: The proposed waterbird distribution indicator (led by JNCC/BTO) should help reflect changes in distribution, including relating to climate change. Is there any additional work relating to climate change that is required to support future assessments?

- There are currently two indicators, one relating to occupancy and the other distributional – presence/absence one looks best.

- Other work has been looking at developing an indicator for distributional shifts to help better understand the impacts of climate change.

- Climate change induced shifts could lead to birds moving to places where there is no or little monitoring, thus posing a risk to future understanding of these populations (Fox et al., 2018).

- Should we consider whether this indicator be included in OSPAR to give it more prominence?

Question 3: Are there any other key gaps that need to be addressed to support waterbird assessment work?

- Functional group reporting needs to be improved as these are more representative of use of marine environment.

- SCARABS – rare annual breeding bird survey by RSPB can provide contextual information (though only for breeding birds).

- There is a requirement to carry out monitoring away from the coast, for example, associated with new marine SPAs.

Question 4: What are the key lessons learned from waterbird indicator work to date?

- Potentially useful. Wintering waterbirds are important but more difficult to monitor than breeding seabirds.

- Need to be careful which species to include. For example, geese are doing relatively well and are included, so this potentially skews results for the existing wintering waterbird indicator as geese are a terrestrial species.

- There is a recognised problem with choosing the baseline. For example, bar-tailed godwits are doing really well but results can depend on the chosen start date from which trends are measured.

- The group questioned whether it is possible to select an arbitrary start point for waterbird monitoring and avoid picking a baseline that reflects a peak. This relates to shifting baselines in the UKMS and needs further work to resolve the issue.

- It might help to do more integrated monitoring (with seabed/plankton monitoring for example) to identify genuine large-scale oscillations and help us to better understand functional changes.

Question 5: What are the priorities for work on waterbird indicators to improve future assessments?

- SMA2020 – not just about focussing on marine species but also geographically focussing on the marine area so that the results better reflect the state of waterbirds in the marine environment.

- Better join-up with other indicators to provide a picture of the marine environment as a whole.

Reference: Fox D et al. (2019) Climate-change not only threatens bird populations but also challenges our ability to monitor them. *Ibis*, **161**, 467-474. https://doi.org/10.1111/ibi.12675

Rapporteur Notes from Group 6 – Inshore fish

Group Facilitator: David O'Brien (NatureScot); Rapporteur: Alison Lee (JNCC)

Question 1: SMA2020 identified the distribution and abundance of inshore fish communities (including transitional) as knowledge gaps, including for prey species relevant to marine mammals and birds – How might these be addressed?

- Inshore fish monitoring needs to be more comprehensive in coverage, both geographically and in the variety of inshore waters surveyed. Survey locations are generally focused on estuaries and reduced-salinity sea lochs, especially those used for aquaculture. A review of monitoring approach, including locations, methods and resources was recommended.

- A higher sampling frequency is also needed to better understand population trends for a complete assessment of the state of inshore fish communities. UKTAG guidance for the Transitional Water Fish Classification Index (TFCI) tool recommends annual sampling and assessment, yet only two sampling rounds had occurred in most Scottish Marine Regions (SMR) between 2010 and 2018.

Question 2: How might we improve our knowledge of the drivers of decline of key species, including in relation to climate change, to support future assessment work?

- Detailed pressure data were not available for the SMA2020 and the report highlighted difficulties in relating pressures to the TFCI assessment results. Pressures on inshore fish communities are varied and likely to increase with climate change, for example, with the northward migration of species associated with warmer waters. A review of pressure recording was recommended, including how data are assessed alongside species data.

- More detailed data on species assemblages and changes within these is also needed. Surveys in the Clyde Estuary SMR show that fish biomass has remained relatively constant, yet species diversity has changed more dramatically, including a loss of some species groups (e.g. elasmobranchs). Communities dominated by smaller-sized fish have also become more common. Similar changes have been recorded in other SMRs.

- A review of monitoring programmes, survey methods and indicators is needed to better understand the drivers of decline and changes in fish community status and trends, including pressures on their essential habitats such as spawning grounds. More data on fishing effort, especially cumulative impacts in nearshore waters is a key gap, for example: where fishing boats are, how many, how often, and what has been caught. This would provide a better understanding of the distribution and intensity of fishing pressures.

Question 3: Are there any other key gaps that need to be addressed to support inshore fish assessment work?

- Gaps in data exist, for example near-shore fish assemblages are missed by International Bottom Trawl Surveys, and data for species of conservation interest (such as shad and sparling) are limited. A gap analysis and revised approach to monitoring is needed, taking a more holistic approach to inshore waters and their varied habitats, boosted by additional methods such as satellite monitoring of fishing boats, support from River Board biologists and citizen science.

- All relevant data should be better collated in one common and freely available repository, to improve confidence in the inshore fish indicator and enhance the application of results.

Question 4: What are the key lessons learned from inshore fish indicator work to date?

- Confidence in the indicator has suffered due to a lack of suitable data. A more structured approach to inshore fish surveys is needed, based around an understanding of the functional value of inshore waters (and their habitats) for both residents and migratory fish. A more holistic assessment of inshore fish is vital given their place in the food chain and importance for birds and marine mammals. A revised approach to monitoring and data collation, supported by increased resources, would lead to a more robust indicator that could better inform future recovery plans and policy decisions.

Question 5: What are the priorities for work on inshore fish indicators to improve future assessments?

- A gap analysis and revised approach to monitoring is needed, taking a more holistic approach to inshore waters and their varied habitats.

- Fill data gaps to survey all critical habitats for inshore fish and capture their whole lifecycle and ecology, especially for sensitive or priority species such as shad and sparling.

- Employ more innovative technology and opportunistic survey methods, e.g. tagging to increase understanding of species presence and movements; genetic sampling to better understand population structures and changes; and explore the possibilities for eDNA and metabarcoding to enhance survey data.

Rapporteur Notes from Group 7 – Biogenic habitats (distribution/extent & condition) & intertidal seagrass

Group Facilitator: Phil Boulcott (MSS); Rapporteur: Sarah Cunningham (NatureScot)

Note: the focus for intertidal seagrass was on resolving the lack of monitoring data.

Question 1: Are there any local or regional anthropogenic pressures or activities of particular relevance for these indicators?

- This is dependent on the biogenic habitat (as per SMA2020 – maerl, flame shell, *Modiolus*, seagrass) and different activities and pressures have varied distributions.

- Kelp was not included as part of the biogenic indicator (due to data availability) but there is potential for its inclusion in future given the extent of kelp and its key role in ecosystem processes. Pressures on kelp extent and depth: harvesting; sedimentation in sheltered areas; and any issues affecting light attenuation (such as high nutrient inputs). Fishing is a lesser issue as most vessels do not enter the rocky, shallower waters of kelp habitat.

- Pressures on biogenic habitats generally: physical abrasion from fishing activity is a key issue. The group noted difficulties with lack of activities data (especially inshore) to inform condition assessments.

- Attributing some impacts is difficult due to their dispersed nature, e.g. pollutants, eutrophication and smothering. River Basin Planning identified point and diffuse sources of pollution; in particular looking at effects on seagrass. It was more difficult to attribute these pressures for biogenic reefs.

- More research and data are needed around the impacts from certain activities/pressures, e.g. cables, renewable developments, seaweed cultivation and fish farming.

- Noted a rapid decline in blue mussels in Scotland and elsewhere in the UK and abroad, possibly caused by a wider-scale issue (e.g. ocean acidification), and locally compounded by other pressures. A NatureScot project is under way and there may be a need for increased monitoring to provide more evidence on the likely cause and potential solutions.

Question 2: Are there any local or regional climatic drivers which should be added or included under the method of existing indicators?

- Species distribution and physical changes are expected under climate change scenarios, with some species more abundant (and others less so) depending on sensitivities. Species spawning, larval development and habitat viability will all be affected by a range of climate effects, e.g. ocean acidification, and changes in hydrodynamics and temperature regimes.

- Incidents of climatic extremes can shape interannual changes (e.g. heat waves, storms) and some biogenic habitats may be particularly sensitive to these with resuspension or removal. Climate data and information need to capture extreme events as well as long-term trends.

- Gaps in knowledge and understanding were identified: mobility of maerl in particular MPAs with increased storminess; ocean acidification effects on habitat viability; larval development and changes in habitat connectivity associated with climate change impacts; interlinkages between human activities and climate change impacts, and potential cumulative effects.

- The implications of climate change for management of biogenic habitats are unclear, especially spatial targeting of measures.

Question 3: Should biogenic habitats indicators be integrated with other data to improve the use of the outputs for management, in particular measuring recovery?

- Yes, specialists need to see the difference between managed and lesser managed areas and what this means for recovery and condition, using a comparative approach.

- Other parameters (such as reefiness) could also be captured to assist interpretation of results, but regional differences may need to be considered when incorporating supporting data to ensure that assessments are undertaken in the relevant context, e.g. for *Sabellaria* in Scotland versus England. Despite this, the group noted the need to define habitats at UK level in order to ensure consistency in reporting.

- The indicator lacks information on condition – an important element for future development. Pressure information is vital in order to achieve this, e.g. the latest fishing activity data. Functional trait analysis would contribute to condition assessment and could be derived from existing monitoring data.

- Measuring long-term resilience via genetic structure and diversity would be a useful development, highlighting more sensitive habitats, e.g. those with low diversity or poorly developed structure.

- Also need to consider new examples of these habitats – how to balance these against losses in other areas – likely a lot of new examples are just ones we didn't know about.

- Under the UKMS the target for 'no net loss of extent' has been diluted, unlike for SMA2020 where this was clearly stated. The group questioned whether this metric would remain aligned between the two assessments.

Question 4: How could data collection be improved in the future, in particular for intertidal seagrass? Working closely with industry, citizen science, etc.

- Interest in MarCLIM type work for other intertidal habitats, e.g. for blue mussels and seagrass (both within and outwith MPAs), using repeated surveys every ~5 years to record changes over time.

- Seagrass data collation and reporting needs resolution. Some seagrass beds not included in reporting due to variability amongst beds, problems with scaling up (or down), or a lack of activity data.

- Greater use of satellite mapping, surveillance drones and more data input to Seagrass Spotter would help collation of seagrass data at larger scales. Other data sources could also be better co-ordinated to provide more data on presence and extent, including: citizen science, SeaSearch, and data from restoration sites (including baseline and post-restoration monitoring data).

- Advances in technology could also enhance data collection for seagrass and other features. DNA and/or eDNA collection via sediment and water samples could be undertaken by a network of rangers, semi-professionals or trained volunteers.

Question 5: What are the key lessons learned from benthic indicator work to date?

- Lack of indicators for application at UK level, with large gaps in the indicator suite, e.g. equivalent to 'Extent of physical damage to predominant and species habitat', OSPAR BH3 indicator.

- Lack of pressure data for condition assessment and/or identifying potential restoration sites. Issues around lack of data, poor resolution and difficulties in attributing pressures (due to the dispersed nature of some). Where modelling is used, appropriate ground-truthing of pressure data is important and habitat suitability models are valuable.

- Collection of data – use of SACFOR problematic for calculating biodiversity indices.

- Standardised data (including metadata) are critical for smooth data flows and consistency in assessment and reporting.

- Repeated monitoring at frequent intervals is valuable to allow identification of short-term versus long-term changes and trends, and full assessment of driving factors (e.g. storm events). Noted that the SMA2020 focussed on the few sites where repeated monitoring was readily available.

- Modelling of recruitment and age structure recommended, providing additional details for habitat distribution and a greater understanding of extent.

Question 6: Do we have the right suite of indicators?

- UK level biogenic habitat indicator has been temporarily set aside due to a lack of data, but options for development should be pursued. A pilot project is under way in Strangford Lough.

- *Sabellaria* – data more readily available now with potentially more in the future. Group noted that there may be an increase in *S. alveolata* with climate change.

- Kelp indicator should be developed, as noted above (question 1).

- Some additional metrics have been tested, e.g. Pielou evenness and Shannon diversity, but have not been combined to assess condition due to gaps in pressure data.

- Potential to include deep sea 'biogenic' or special habitats which may have a similar restricted distribution.

Rapporteur Notes from Group 8 – Deep-sea vulnerable marine habitats & deep-sea fish

Group Facilitator: Cristina Vina-Herbon (JNCC); Rapporteur: Rachel Boschen-Rose (MSS)

Overall key messages:

1. Collaborative cross-sector work (academia, industry, government/public bodies) is needed to help address data gaps and share the cost of deep-sea surveys and research. This type of collaboration on surveys is needed to provide the underlying datasets that will be used in indicator-based assessments for the deep sea.

2. Robust assessment of deep-sea fish and benthic habitats relies on long-term time series information. This necessitates both a commitment to continue existing time series and a commitment to initiate new time series in priority locations. Long-term time series information will help to assess the impacts of climate change on the deep-sea environment and to establish baselines against which to measure human-induced change. Given the potential logistical and resourcing challenges associated with committing to deep-sea time series, there needs to be effective communication around the clear policy need for long-term time series information and how the information will be used by government bodies and/or policy customers.

Question 1: Are there additional indicators beyond those used in SMA2020, for example OSPAR, that could be used to support the assessment of deep-sea ecosystems in future SMAs? Could existing indicators used for shallow-water ecosystems be applied or adapted to deep-sea ecosystems?

Key summary points:

- The deep sea is a challenging environment to access, sample, and monitor. As a result, deep-sea fish and habitats typically have larger data and evidence gaps than those in shallow-water environments.

- Some of the assessment gaps for deep-sea fish and habitats in the 2020 Scottish Marine Assessment could potentially be addressed, at least in part, through applying or adapting existing indicators from shallow-water environments. However, limitations in the underlying data for deep-sea fish and habitats could make it challenging to apply shallow-water indicators for the deep-sea environment and could reduce their effectiveness.

- Previous work, such as that conducted by the H2020 ATLAS Project (Kazanidis *et al.* 2020), can help to inform decisions on how indicators could be improved for the deep-sea. Data and information collated as part of ongoing OSPAR assessments for Threatened and Declining (T&D) habitats and species could be re-examined to extract data and information to support the assessment of Scottish deep-sea habitats.

Additional points for question 1:

- In terms of OSPAR assessments, the underlying data and information for T&D assessments cover some deep-sea habitats and locations within Scotland. For example, information on *Lophelia* coral reefs, carbonate mounds, seamounts, coral gardens, and sponge aggregations. Information available within or underpinning the OSPAR assessments includes ground-truthing and expert judgement. OSPAR information could be extracted to better inform the next Scottish Marine Assessment for deep-sea habitats.

- Differing amounts of information are available for deep-sea fish and deep-sea benthic habitats. For deep-sea fish there are long-term datasets to draw on, at least for some locations, making it easier to determine trends. For deep-sea benthic habitats, long-term datasets are typically lacking, making it harder to determine trends or measure impacts.

- There are additional surveys, some conducted over long time periods, generating samples or data that could help address deep-sea data gaps. For example, plankton water column surveys down to 200m that cover Scottish waters out to Hatton Bank every three years. Samples collected from the plankton survey could help assess benthopelagic interactions, including linkages between surface water primary productivity and food supply to the deep sea and connectivity and dispersal of deep-sea species where eggs or larvae occur in surface waters. Ultimately, detecting declines in surface waters in terms of reproductive propagules or primary productivity could be used to predict declines in deep-sea fish and habitats.

Question 2: SMA2020 considered deep-sea fish to have no discernible trend. How could existing indicators be applied or developed to help clarify trends in deep-sea fish?

Key summary points:

- The spatial and temporal coverage of survey data for deep-sea areas is not equal, with some locations being more comprehensively and consistently surveyed than others. Deep-sea fish data collection has traditionally focussed on areas targeted for fishing. For example, fisheries data has been collected more extensively from Rockall Bank than towards Hatton Bank.

- The current suite of indicators does not provide effective assessments for some deep-sea fish groups, such as sharks, where the general recovery of the deep-sea shark community linked to the 800 m bottom-trawling ban is not being picked up by the current indicators.

- Using pre-defined geographical assessment areas based on policy needs could impact the ability of indicators to effectively detect changes in the deep-sea fish community. The existence of biogeographic boundaries and depth-related trends should be considered when determining assessment areas.

Additional points for question 2:

- Indicators currently being used do not effectively address species that move between the inshore and deep-sea environments as part of their life cycle. Effective indicators for these species could improve the ability to assess the linkages between inshore and offshore habitats for some commercially important or sensitive deep-sea fish species.

- Consideration needs to be given to how existing indicators for fish could be better applied to deep-sea fish. For example, maximum fish length is not the best indicator for deep-sea species that tend to have longer bodies more generally. Biomass-based indicators, or a combination of biomass and length, merit further consideration for deep-sea fishes.

- Data for some deep-sea fishes are regularly sent to ICES; the datasets held by ICES could aid in Scotland-focused deep-sea fish assessments and the application of indicators.

- Linking with additional datasets, such as fisheries data from ICCAT, could help to address some of the gaps related to assessing status and trends for tuna and sharks within the Scottish deep-sea although there may be challenges associated with integrating data sources from different jurisdictions and competent bodies.

Question 3: SMA2020 considered (subtidal) biogenic habitats to have decreasing tends. Are suitable indicators available to assess deep-sea biogenic habitats (e.g. cold-water coral reefs) for similar trends? If not, how could existing indicators be developed to support these assessments?

Key summary points:

- Underlying data from ongoing OSPAR assessments such as those collected under T&D assessments, complemented by other data sources, could be used to assess the status and trends of deep-sea biogenic habitats in Scotland, such as *Lophelia* cold-water coral reefs.

- Indicators used in the Scottish Marine Assessment 2020 to assess shallow-water biogenic habitats should be explored to see how these frameworks could be applied to deep-sea biogenic habitats, where sufficient data are available.

Question 4: What are the lessons learned from deep-sea ecosystems indicator work to date?

Key summary points:

- Using deep-sea locations with more comprehensive data coverage as case studies enables new assessment approaches or indicators to be trialled and show-cased with a robust evidence base. This is particularly important as there is typically less information available for deep-sea fish and habitats compared to shallow-water environments, and it may not be possible or appropriate to apply shallow-water indicators to all deep-sea areas.

- Processes in the deep sea are typically slower and these environments need to be surveyed and monitored for longer periods to detect change, particularly against a backdrop of natural variation across multiple spatial and temporal scales. Data need to be collected over long (decades) time periods in the same location with the same methods to be provide appropriate datasets for indicator-based assessment.

- The methods used to calculate deep-sea indicators need to be able to account for the discovery of ‘new’ deep-sea habitat occurrences as exploration of the deep-sea environment continues. Otherwise, new habitat occurrences could artificially inflate the status or trends for these habitats.

- To provide suitable data to inform indicator-based assessments for the deep sea there needs to be a cross-sector collaborative approach to deep-sea surveys, research and monitoring. Collaboration amongst academia, industry and government/public bodies is needed to address the logistical and financial challenges of providing robust deep-sea datasets.

Additional points for question 4:

- Providing robust datasets for indicator-based assessment would benefit from data collection and archiving standardisation, including metadata, to make records accessible.

- Where data sets are needed for sensitive habitats or protected sites, further consideration is needed on how non-destructive data collection can support indicator-based assessments, for example the use of digital imagery (stills and video).

- Further consideration is needed on how to maximise data collection opportunities in deep-sea environments, particularly for benthic species. For example, some deep-sea fisheries surveys conducted during daylight hours provide the opportunity to conduct benthic imagery-based surveys overnight. Further opportunities for added value work could be the collection of data on environmental parameters, eDNA or physical samples of benthic organisms where physical sampling is permitted.

Question 5: What are the priorities for work on deep-sea ecosystem indicators to improve future assessments?

Key summary points:

- To move towards an ecosystem approach for deep-sea assessments, a greater number of species need to be assessed, particularly sensitive species, going beyond the biogenic habitats that are typically assessed.

- Robust indicator-based assessments of deep-sea fish and habitats need more time series information, including continuation of existing time series and development of new time series to address knowledge gaps.

- Deep-sea indicators need to be ecologically meaningful but also to have a clear link back policy needs. For example, looking at changes or improvements in status and condition of elasmobranchs and the wider ecosystem around the 800 m depth band to linked to the bottom-trawling ban at this depth.

- Additional indicators are needed to assess for connectivity in the deep sea, such as trophic connectivity (food webs) and genetic (population) connectivity. These connectivity indicators have clear links to policy, for example supporting assessments of MPA network connectivity and connectivity amongst Scotland’s marine regions.

Additional points for question 5:

- The ongoing effects of climate change and their consequences, for example ocean acidification, are poorly known in the deep sea. Provision of long-term time series information could help address this knowledge gap and could form the underlying dataset for indicators that specifically assess climate change effects in the deep sea.

- As species ranges change in response to climate change, there needs to be a framework for assessing these changes, and the introduction of invasive species, for deep-sea fish and benthic habitats.

- Deep-sea ecosystem functioning is not currently assessed using indicators and a framework for this is needed. There is potential for an exploratory study using deep-sea fish data to develop and trial an indicator that can assess changes in trophic linkages for this biological group.

Reference: Kazanidis *et al*. (2020) Assessing the environmental status of selected North Atlantic deep-sea ecosystems. *Ecological Indicators*, 119: 106624. https://doi.org/10.1016/j.ecolind.2020.106624