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Making progress towards integration of existing sampling activities to establish Joint Monitoring Programmes in support of the MSFD

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ABSTRACT

Data support for GES assessment under the MSFD will require subregion-scale Joint Monitoring Programmes (JMPs). These JMPs must be cost-efficient and produce the necessary evidence-base to support management decisions. This review summarises the outputs of a 2.5-day multidisciplinary workshop where scientists and programme managers developed monitoring scenarios as examples of how current sampling activities could be extended and combined into framework JMPs. The objective was to explore opportunities for improved i) integration of monitoring, ii) international collaboration and iii) multidisciplinary use of platforms. The workshop identified opportunities to upgrade current monitoring programmes, to include additional sampling activities, and to support integration of resources and activities. We found that developing JMPs using this bottom-up approach has potential benefits but requires commitment and expert coordination. Coordination needs include definition of data requirements, common sampling methodologies and data exchange.

1. Introduction

The Marine Strategy Framework Directive (MSFD, 2008/56/EC) aims to achieve Good Environmental Status (GES) in European Union (EU) waters by 2020. The North East Atlantic MSFD Region is divided into four subregions: the Atlantic Ocean, the Bay of Biscay and Iberian coast, the Celtic Seas and the Greater North Sea (NS). Each EU Member State (MS) is required to develop a marine strategy for its EEZ, and these MS strategies are typically coordinated by national groups, e.g., MARG in the UK and BIOMON in the NL. However, GES must be achieved at the subregion scale. The MSFD assesses GES using 11 descriptors (D1-D11) in line with the Ecosystem Approach (e.g., [1,2]), and state under each descriptor is monitored using a suite of indicators. The spatial extent, habitat heterogeneity, and ecological diversity of MSFD subregions are a challenge for the development of monitoring programmes (MPs) to support these state indicators, especially for ecosystem components that extend across EEZs. MSFD 2008/56/EC states that MPs must be in place by 2014 and that implementation must be achieved by 2016; the next review of the process commences in 2018.

At present, available data support varies among MSFD indicators; some have no current dedicated MP, while others (e.g., chlorophyll concentration) are already monitored at MS level. An exemplary case is the D3 Commercial Fish indicators. These metrics use data from coordinated international surveys, e.g., the International Bottom Trawl Survey (IBTS) (http://www.ices.dk/marine-data/data-portals/Pages/DATRAS-Docs.aspx) which support stock assessments for target species. In general, existing EU marine monitoring is at relatively small spatial scales [3] and there are still data gaps [4]. Incomplete coverage elicits frequent calls for extended monitoring of the marine environment (e.g., [5]), but

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much discussion of the practical needs and costs of extended monitoring has been described by the ICES Science Steering Group on Integrated Ecosystem Assessment (SGIEA) as 'a spiral of "What do you want?-Well, what can you deliver?" questions'. This debate highlights the tension between the economic cost of MSFD MPs and the need to produce data that are fit for the purpose of supporting state indicators [6]. The expectation is that extending existing monitoring activities will be more cost-efficient than establishing completely new MPs; full data-support will require additional activities but it may be possible to add these to existing or integrated MPs to create MSFD-targeted Joint Monitoring Programmes (JMPs). Established monitoring time series have added value in defining GES targets and assessing changes in state. JMPs should 'provide data relevant to different MSFD descriptors, criteria and indicators, to different pieces of legislation, for more than one MS' [4]. New data streams can be collected in a comparable way or independently quality-assured.

The key forum for regional coordination of the MSFD in the NE Atlantic is the OSPAR Regional Sea Convention. An OSPAR pilot study in the North Sea identified Ecological Quality Issues (EcoQIs) analogous to MSFD descriptors. EcoQI state in relation to reference levels (Ecological Quality Objectives, EcoQOs) is monitored using indicators. OSPAR is now working to develop a series of common indicators and, where appropriate, will establish coordinated monitoring to support those indicators. The EU JMP project ('The Joint Monitoring Programme: North Sea/Celtic Sea-JMP NS/CS') has catalogued metadata on the data needs of MSFD indicators (http://jmpnscs.mumm.ac.be) and current monitoring activities. We use selected case studies from the NS to ask questions (Table 1) about (i) whether extending and/or pooling existing monitoring resources can underpin multidisciplinary JMPs with potential to efficiently supply MSFD monitoring data, and (ii) key potential constraints on this process, therefore offering recommendations on how to proceed and overcome challenges. The actual development of functional JMPs is a further and much larger-scale challenge, but our current questions apply to any MSFD subregion. The monitoring plans from all MSs have been submitted to the EU for consideration (under MSFD Article 11 of their MP by 15 October 2014). There were clear differences in the coherence of MS's monitoring level across regions and sub-regions. However, it is expected that there will be some opportunities for further integration across some of these aspects during the implementation process (e.g., indicator development, monitoring and assessments). A clear message is that most MS MPs currently contain only limited analysis of pressures and impacts [7].

2. Methods

2.1. Background and workshop format

As a dedicated activity under the EU JMP: NS/CS, we convened a workshop in 2014. Partners in the EU JMP consortium proposed a list of experts who could potentially (i) participate in a mind-map session, and (ii) contribute to diversity of science/policy/management expertise. About 20 participants were selected such that countries, project partners and fields of expertise were represented. Prior to the workshop, all selected participants received an invitation and a questionnaire addressing current national MPs and data gaps. Case studies (*chlorophyll*, *demersal elasmobranchs* and *benthos*) were used to focus discussion and were selected to represent the diversity of ecosystem components addressed by the MSFD [3] (see Table 2 for associated descriptors). The EU FP7 project DEVOTES (http://www.devotes-project.eu) has produced a catalogue and critique of existing EU marine monitoring networks; in a plenary session, we constructed a mind-map identifying technical and practical opportunities to extend such existing MPs to better serve the data needs of workshop case studies and other descriptors. Participants subsequently worked in case-study subgroups according to expertise.

Table 1
Questions addressed by case study subgroups at a workshop on MSFD JMPs.

Questions
Which data related to the case study will be collected?
Which existing monitoring will be taken into account?
Which techniques will be used?
Which platforms will be used?
Which countries will be involved in data collection?
Which additional data will be collected and to which MSFD descriptor/indicator do they relate?
Which resources do you need to collect the information needed?
Will existing monitoring be influenced by the new data collection? If yes, how (e.g., spatial, temporal, number of stations)?

2.2. Case study ecosystem components

The first step was to discuss the data requirements of MSFD indicators pertinent to workshop case studies:

2.2.1. Chlorophyll in the Greater North Sea subregion

Statutory monitoring of chlorophyll is undertaken for the Water Framework Directive (WFD), with limited overlap with the MSFD and the OSPAR Comprehensive Procedure (COMPP). Borja et al. [1] suggest that some of the eutrophication parameters and assessment tools used in the WFD are probably applicable in the MSFD, e.g., indices for phytoplankton and chlorophyll a. They also highlight that intercalibration for the WFD has helped highlight the ecological meaning of good state. National reports submitted under Article 11 of the MSFD indicate that several different metrics and methods are currently assessed against regionally varying thresholds [8]. However, the 'top down' approach to monitoring taken by the MSFD may facilitate expert agreement on whether the same level of understanding on ecological functioning has been achieved [1].

2.2.2. Demersal elasmobranch species in the North Sea and Celtic Sea

Elasmobranch fishes are sampled in various fisheries-independent surveys, e.g., the IBTS, which provide abundance data used in assessment of commercial stocks. Many elasmobranch species are considered data poor, and assessment comprises abundance trend analysis without management reference points [9]. Healthy elasmobranch populations will be required to fulfil aspects of several descriptors (see other descriptors in Table 2) and indicators (see results).

2.2.3. Benthic habitat condition

MSs evaluate benthic habitat condition under various environmental directives, and with a variety of assessment approaches, e.g., multi-metric benthic indicators (see below) [10]. Most approaches rely on habitat-stratified species-abundance data, collected with a variety of sampling gears. Currently, there is no common methodology, but there is existing literature that helps to integrate different data sets. There are also methods in place to enable data to be comparable and allowing different monitoring programmes to be combined. (These lessons and methods have been known for many years [2, 11–13]). The NS Benthos Surveys in 1986 and 2000 [13] are a clear example of where data sets were collected and then integrated for analysis under a coordinated international benthic sampling programme.

Table 2
JMP mind-map results by workshop case study. These outputs were derived from open discussion based around a series of questions (Table 1).

		Chlorophyll (Chl)
Existing monitoring	i.	Existing fixed point monitoring stations: Smart Buoys and Marnet.
	ii.	Regular (weekly and monthly) sampling stations.
	iii.	Existing WFD inshore monitoring sites.
	iv.	Existing ferry-boxes installed on research vessels and ferry routes.
Add-on monitoring	i.	New fixed monitoring locations for regular water sampling at platforms of opportunity: Oil and Gas platforms.
	ii.	Remote sensing; satellite imagery converted to regional Chl concentration. Validated using direct measurements at fixed stations.
	iii.	Ad hoc oceanographic sampling and fluorometry data, and long term oceanographic sections.
Costs	i.	Oil platform water sampling and analysis. Additional cost will be small in relation to the scale of the current programme.
	ii.	Improving the calibration of ferry-box fluorometers will also incur additional costs in calibration sampling and sample analysis
	iii.	Additional staff time resource will be required to fully develop the remote sensing validation programme for the North Sea.
Considerations	i.	Consistent methodologies for Chl analysis (total by fluorometer, pigments by HPLC) and calibration of fluorometers by direct analysis of water samples.
	ii.	A consistent approach to Remote Sensing validation.
	iii.	Statistical approaches to assess multiple data types/frequencies across the region and growing period. Assessment of 90th percentile against thresholds.
	iv.	Agreement of regionally specific thresholds to apply in assessment
Other descriptors	i.	Eutrophication (D5); Biodiversity (D1); Hydrographical condition (D7); Non-indigenous species (D2).
	ii.	Phytoplankton & zooplankton (D5, D1 and 4).
	iii.	Marine litter – floating litter and microplastics (D10).
	iv.	Non-indigenous species (CEFAS SmartBuoys have settling plates) (D2).
	v.	Carbonate chemistry for ocean acidification.
	vi.	Contaminants, metals – including passive samplers (D8)
		Demersal elasmobranchs
Existing monitoring	i.	International Bottom Trawl Survey and Beam Trawl Survey.
	ii.	Landings records for commercial species.
	iii.	Data on discarding of commercial and non-target species from observer schemes.
Add-on monitoring	i.	Expand fishing vessel observer scheme: target collection of biological data on elasmobranchs according to a standardized protocol.
	ii.	Tagging of caught individuals; with archival tags and/or satellite pop-up archival tags depending on goals. Biological information and spatial/temporal distribution.
	iii.	Egg case sampling on beaches or dedicated benthic surveys.
Costs	i.	Training observers and scientists in species ID and DNA analysis.
	ii.	Salary for data collection, analysis and reporting.
	iii.	Additional vessel time to visit areas of ecological importance.
	iv.	Tag costs, including recovery fees and Satellite ‘time’.
	v.	Beach combers digital ‘app’ for mobile devices (egg case reports).
	vi.	National contact person for the observer/egg case schemes.
	vii.	Operationalising the oil platform water sampling and analysis.
Considerations	i.	Commercial fishing effort is not focused on elasmobranchs, so possible spatial and temporal mismatch.
	ii.	Focus on improved Species ID.
	iii.	Raise public awareness, and enhance involvement, e.g., in egg case scheme.
	iv.	Recovery rate and technical problems with tags.
	v.	Storage of additional data and biological samples.
Other descriptors	i.	Fish community data for D1 biodiversity indicators, e.g., presence/absence; D2 non-indigenous species; D3 commercial fisheries indicators, D4 food web indicators, and D10 marine litter.
	ii.	Monitor D10 beach litter during beach sampling for egg cases.
	iii.	D1 biodiversity and D3 commercial fisheries.
		Benthic habitat condition
Existing monitoring	i.	National monitoring programmes (integrated, multidisciplinary monitoring covering multiple descriptors in some countries).
	ii.	IBTS and North Sea Beam Trawl Survey (BTS).
	iii.	Industry sampling (i.e. for windfarms or oil and gas).
	iv.	Eutrophication and MPA management surveys.
Add-on monitoring	i.	Fish stomach analysis.
	i.	Acoustic techniques (e.g. MBES bathymetry and backscatter).
	iii.	Underwater optical techniques.
	iv.	Substrate and habitat extent and distribution.
	v.	Quantified seafloor pressure data (e.g., VMS, trawl marks on sonar, dredging intensity).
Costs	i.	Staff time for sampling, data/biological analysis/interpretation.
	ii.	Storage and handling of formalin (e.g., COSSH in UK).
	iii.	20–60 min platform time per sample (depth dependant).
	iv.	Specialised equipment for data collection (e.g., Grab, Dredge).
	v.	Operationalising oil platform water sampling and analysis.
Considerations	i.	Group to coordinate and integrated benthic monitoring.
	ii.	Define sample resolution (temporal and spatial coverage). Define relationships between monitoring efficiency and sample size.
	iii.	Data collection methods and designs (e.g., temporal and spatial coverage) need to be integrated among member states.
	v.	Technique R&D may be necessary.
	vii.	Extended data QA/QC, standardisation and dissemination.
	viii.	Flexibility in funding streams.
Other descriptors	i.	Grab content for marine seafloor litter (D10) and foodwebs (D4).
	ii.	Pressure State Analysis for seafloor integrity (D6).
	iii.	Organic matter for foodwebs (D4).
	iv.	Chemical analyses on biota for contaminants (D8).
	v.	Non-indigenous species (D2).
	vi.	Sandeels for commercial fisheries (D3) and foodwebs (D4).

2.3. Identify monitoring opportunities

Workshop case-study groups were asked to report on three scenarios, being:

1. JMP considering existing (non-dedicated) monitoring.
2. JMP considering existing monitoring and other information sources.
3. JMP incorporating all information, including potential dedicated monitoring.

Scenarios were constrained by a set of questions (Table 1), and developed under defined headings: (i) Existing monitoring, (ii) Add-on monitoring, (iii) Costs, (iv) Additional considerations, and (v) Other descriptors (Table 2). Participants were instructed that scenarios could incorporate ideas from the plenary mind-map but should comprise tractable approaches to monitoring, i.e., considering the technical and practical limitations of given methods. Scenarios should conform to available financial and survey resources, e.g., additional monitoring activities must not add significant cost or time. Data should be collected with a scientifically recognised method. Data quality should be specified and the potential for combining datasets discussed. Case study groups presented their scenario as a bullet-point JMP. These JMPs are only initial and exploratory ideas of what it may be possible to develop and implement in practice - the intention was to evaluate how easy it might be for an expert group to assemble credible JMPs for given MSFD descriptors, and to highlight important issues for this process.

Various statutory and national bodies currently conduct marine monitoring to serve legislative requirements of the EU WFD and Habitats Directive. These programmes are partly coordinated by the regional seas conventions (OSPAR and HELCOM), and address aspects of water quality (including plankton), and the population dynamics of fish, seabirds and marine mammals. Other monitoring is maintained by academic studies, including a number of international collaborations under the EU FP7 scheme (see [14] for examples). The important job of collating information from academic studies, and making it available to MSFD policy makers has been undertaken by the FP7 project STAGES. Environmental NGOs and interested member of the public also contribute to some monitoring programmes, e.g., for beach litter or algal blooms. Zampoukas et al. [14] caution that limitations in the use of data collected by non-experts should always be considered, and suggest that ‘public observation parameters should be carefully chosen to allow ensuring validation, QA/QC routines and some confidence in the observations made’. Quality assurance (QA) and quality control (QC) measures ensure that monitoring results fulfil stated quality and support a transparent and reproducible analytical process.

The concept of GES relies on assessing a whole marine area (e.g., an MSFD subregion). This is problematic when the majority of the monitoring is restricted by national boundaries. There are only few examples where the monitoring is co-ordinated over a whole area for assessments (e.g., the IBTS). Achieving GES may also be influenced by climate change, particularly in areas where climate change may interact with human-induced change [15].

3. Results and discussion

3.1. Case study JMPs

For each case study, an outline JMP is reported (Table 2). The primary purpose of these outlines is to illustrate the apparent wealth of opportunities to develop JMPs without establishing entirely new surveys. Monitoring must be seasonally fixed across all programs and follow agreed methodological standards. Standards exist for elements of most MSFD descriptors (see [16]), including chlorophyll (e.g., CEN guidance on use of in vivo absorption techniques for the estimation of chlorophyll-a concentration in marine and fresh water samples) and benthos (e.g., ISO 16665 norm for quantitative sampling and sample processing of marine soft-bottom macrofauna). Such methodological standards support the need for comparability of approaches in determining GES and environmental goals within and among marine regions [16]. Data would comprise species-abundance, biomass and composition. All NS MSs would contribute, and integration of existing datasets would allow temporal extension of regional time series. A co-ordination group was considered important to successful implementation.

3.1.1. Chlorophyll in the Greater North Seas subregion

The case study group imagined a multiplatform international chlorophyll MP for the NS. This would combine empirical measurements with validated remote sensing of offshore waters. Stratified sampling would occur in the ‘growing season’ Mar–Oct, and samples be integrated to calculate assessment values. Measurements comprise direct water sampling, flourometry (vessel deployed instruments, moorings and underway monitoring) and remote sensing. Samples are analysed using various techniques that target photosynthetic pigments. Standardisation is required in monitoring and analysis techniques, assessment methodology and threshold setting, while allowing flexibility for innovative monitoring approaches. Proposed modifications to current chlorophyll sampling activities should consider additional data already collected during non-dedicated MPs.

3.1.2. Demersal elasmobranchs in the Greater North Sea and Celtic Seas subregions

Existing fisheries survey data can support many D1, D3 and D4 indicators, e.g.,

i. Distribution of the species: % occurrence (number of hauls in which a species was found/total number of hauls carried out, by year).
ii. Population abundance: CPUE by year.
iii. Differences in abundance.

The case study group sketched an elasmobranch JMP that focused on optimising existing MPs supporting these indicators. This approach reflects the availability of ongoing coordinated international fisheries surveys. Key issues for improvement were identified as limited spatial and temporal coverage of elasmobranch distributions and inaccurate species identification.

3.1.3. Benthic habitat condition in the Greater North Sea

The Benthic communities and habitats in the North Sea have been studied for many decades. There are well-established protocols for sampling these communities (e.g. [17,18]). The (draft) OSPAR ICG-COBAM common approach for benthic habitat assessment suggests that benthic multi-metric indicators (see http://www.devotes-project.eu/devotool/) are essential for determining habitat condition. We decided not to consider the indicators themselves, but the underlying variables and parameters, e.g.,

i. Species biomass, abundance and richness.
ii. Bray–Curtis similarity (measures of species composition (turnover)/community hetero-/homogeneity).
iii. Species sensitivity (AMBI, $\sum ES50_{0.05}$).

The proposed benthic MP was based on a hierarchy of scales: (1) NS wide, (2) Dedicated national surveys in MPAs and/or highpressure areas (risk based monitoring), and (3) Data from compliance monitoring by industry; data from industry platforms are not currently included in the MSFD, but closer collaboration in fulfilling monitoring and statutory obligations could be fruitful. State assessment of non-indigenous species and pathological anomalies can be derived incidentally from these datasets.

3.2. Existing monitoring

Workshop participants were often pleased to recognise the number and diversity of existing MPs, the potential to add value by integrating existing data, and the current extent of data collection beyond primary monitoring objectives (see DEVOTES for full catalogue). This stimulated ideas for extending and integrating these programmes (see Table 2), although economic constraints and the need to sustain long-term data sets were consistently highlighted.

3.3. Add on monitoring

Case study groups were able to identify numerous opportunities to combine and extend current MPs (see Table 2 for examples). Many of these opportunities use available platform space in a more efficient way and/or exploit survey downtime.

3.4. Costs

A key issue identified with extended monitoring is economic cost – the workshop assumed that supplementary funding would not be available. We found that much progress in data collection could potentially be made with additional costs restricted to sampling equipment, staff salary/training, and data storage/analysis (Table 2). These costs are likely to be small relative to contracting additional survey platform time or the development of new MPs.

3.5. Additional considerations

Several common themes emerged that should be considered when moving towards a JMP based on integrating and coordinating existing monitoring activities:

3.5.1. Data exchange

Data exchange, exploration and sharing are crucial in joint monitoring. Combining, exploring and analysing data from current MPs should be encouraged before deciding if more data is needed or if alternative data are preferable. When assessing GES, data sets will typically have to be integrated at subregion scale. Parallel data series for given subregions should be exchanged to minimise duplication and facilitate consistency – this is underway among some MSs. For some descriptors, international data exchange is already well established with collaborative data repositories (e.g., ICES, EMECO, EMODnet). The European Marine Observation and Data Network (EMODnet, http://www.emodnet.eu) is a 'long term marine data initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) underpinning its Marine Knowledge 2020 strategy'. EMODnet provides access to marine data from the following themes: bathymetry, geology, physics, chemistry, biology, seabed habitats and human activities.

3.5.2. Accuracy and precision

Joint monitoring often means combining multiple methods on one platform, this combination is facilitated by robust standard operating procedures (SOP). The accuracy and comparability of data collected is a key requirement for the assessment and description of environmental status and for the assessment of anthropogenic influences and required measures. Quality assurance (QA) and quality control (QC) measures ensure that monitoring results fulfil stated quality and support a transparent and reproducible analytical process. Even so, extending sampling activities cannot be carried out endlessly without compromising data quality. Before setting up multiple-objective JMPs, it is important to estimate the statistical power needed to detect change in given indicators. This will constrain how many data types can be collected without losing precision and accuracy, and is key to producing data that are fit for purpose [6]. Scientists must continue to work closely with policy makers to disseminate scientific findings and to define acceptable uncertainty limits for detection of change in environmental state. Such collaboration will ensure that management thresholds and policy decisions reflect scientific evidence.

3.5.3. Sampling techniques

International agreement on methodologies facilitates joint monitoring and data interpretation (see discussion of CEN and ISO standards above). For some descriptors having prescriptive indicators, e.g., contaminants (D8), sampling methods may already be similar among MSs [19]. Signatories to the OSPAR Joint Assessment and Monitoring Programme (JAMP) already undertake coordinated monitoring of water quality variables [20]. In other cases, established MPs may differ between MSs, and certain sampling techniques may not be acceptable in all MSs. This variation should be considered when choosing consensus methodologies - technical developments may provide scope to enhance sampling without changing methodology. Given agreement on sampling technique, the central NS may provide a good opportunity for international calibration/validation. When planning standardized methodology, the value of maintaining existing time-series should be considered; comparative sampling and subsequent analysis must quantify the effect on a data series of alternative methodologies. The WFD offers some useful guidance on how these issues may be addressed and overcome [1]. A relevant example is the development of new approaches to support definition of WFD coastal types for intercalibration. Identifying ecologically appropriate sampling scales is now a key problem for the MSFD, which was initiated on the principle of assessing GES at (large) subregion-scale. Implementing monitoring and assessment for the MSFD now demands robust definition of habitat types, their distribution within given subregions, and monitoring programmes that capture state across all the important components of a subregion.

3.5.4. Calculation of indicators

As all MSs have to report on GES, internationally agreed methodologies for data processing and reporting will help to integrate results over wider scales and to facilitate interpretation. Processing differences could confound separate data series even when sampling method is identical. An important issue is if/how similar datasets might be combined to extend indicator time series. This may be possible when sampling gear and methodology are similar and times series record similar values over some standardisation period. However, the very low precision of many MPs, even the IBTS fish surveys, means that data series may have to be considered separately and perhaps integrated at a higher level using some GES decision rule. Coordination of MSFD implementation by Regional Sea Conventions (RSC) includes definition of common indicators, assessment and determination of GES. Following the submission of MS monitoring strategies in 2014, the EU Commission met with MSs that are contracting parties to the four RSC. The OSPAR meeting concluded that MSs should 'Continue working together to improve adequacy and coherence of the MSFD implementation addressing the recommendations of the

Commission in a coordinated way' [8].

3.5.5. Coordination

International coordination of monitoring can improve sampling efficiency and facilitate agreement on sampling and data processing methodologies. For example, OSPAR has set up a dedicated group to improve cross border collaboration. The main goal is to improve adequacy and coherence of MSFD implementation over the period of 2014–2018 (http://ospar.org/html_documents/ospar/html/ospar_regional_plan_action_msfd_imp.pdf).

Coordination and shared economic input across MSs creates a cooperative framework that broadens data ownership and could simplify data exchange. Facilitating wider end user access should follow. For both chlorophyll and benthos sampling, it is recommended that national coordination groups increase integration at EU scale. Benthic monitoring is currently co-ordinated under the ICES BEWG, where there is agreement (an ISO standard) on how data are collected, analysed and reported. The ICES fisheries survey planning groups also represent a very useful template for a coordination framework that is amenable to application of QA/QC. An incidental advantage is that international staff exchange promotes personal relationships and shared perspectives, potentially leading to re-evaluation of procedures.

During international monitoring (e.g., the IBTS), MSs often sample outside their national EEZ. It would be valuable to simplify the current international permit process for such cross-border sampling. At present, research vessels planning to sample in the waters of another MS are obliged to submit a request up to six months prior to the event. This request specifies the number and type of samples to be taken. The process is obviously not amenable to a flexible MSFD subregion-scale monitoring programme. A final issue is data collation: data from different MSs currently tend to be collated on a fairly *ad hoc* basis, although international bodies such as ICES provide limited support. Pan-European virtual platforms could serve as a forum for data collation and exchange, and might also highlight data gaps.

3.5.6. Adding activities to current monitoring

Sampling platforms are expensive, and should be used as efficiently as possible. Many ship-based surveys could undertake additional data collection during downtime, e.g., night-time during current 12-h operations, or using 'spare' days planned as a bad weather contingency. Free space for staff or hardware may also be available, e.g., during ferry-box sampling. The ferry-box, provides an automated instrument packages, helping to collect many data sets from the "Continuous Plankton Recorder (CPR)" with its single purpose of collecting plankton samples during regular ship cruises up to most sophisticated "FerryBoxes" with an ensemble of different sensors and biogeochemical analysers (http://www.ferry-box.com/about/principle/index.php.en). Some surveys could be extended to consider a range of ecologically-relevant trophic levels; the NE Atlantic mackerel egg survey is a coordinated international ecosystem monitoring exercise that covers a swathe of ocean from Biscay to Norway, and collects data on the pelagic environment, plankton and fish. However, there are logistical limits to the amount of work that can be done on a single survey, and primary survey objectives (defined by funding source) will typically take priority. Precise definition of additional data needs, sampling protocols, automated methods and cost incentives will increase the likelihood that requested secondary data are collected in an efficient and rigorous manner. Flexibility in the planning of MPs may also facilitate secondary data collection.

3.5.7. Outsourcing data collection

Outsourcing could take many forms, e.g., volunteers from the UK Marine Conservation Society NGO currently carry out beach litter monitoring. This raises ethical questions about an MSFD implementation that relies on voluntary groups, but may be justified by the growing profile (and occasional success) of 'citizen science'. In all cases, training and a well-defined sampling protocol are necessary to ensure data quality and continuity. An effective dissemination strategy is also important-information on achievements and potential data-use motivates people to maintain sampling efforts not directly related to their job specification.

3.5.8. Governance and policy constraints

It is necessary to further elucidate potential governance and policy constraints on altering existing national MPs (see CEN and ISO standards above). Issues may include national jurisdiction and the logistics of redistributing monitoring tasks between nations. One potential mechanism may be to establish a central fund for certain international MPs, with funds being distributed according to tasks fulfilled.

3.6. Potential additional data collection

Several existing MPs collect data that can support indicators across different MSFD descriptors. Case study groups identified opportunities for such multidisciplinary monitoring, noting that success will require coordination and international data exchange.

4. Conclusions and recommendations

Our workshop successfully identified many tractable bottom-up routes towards combining existing MPs into dedicated JMPs (Table 2; see the DEVOTES monitoring catalogue for a comprehensive summary). We recognize the challenge of reconciling economic efficiency with collection of robust scientific data that can support policy decisions.

Development of JMPs: Framework MSFD JMPs could be efficiently developed by integrating and coordinating existing MPs, and by using 'free' platform time for additional sampling. Strategic support from international expert groups such as the ICES SSGIEA will help monitoring groups from different MSs to produce fit-for-purpose data that can be integrated through EU level coordination groups for assessment of GES at subregion scale.

Integration of existing data sets: There is a need to jointly evaluate and better integrate existing datasets for MSFD subregion-scale assessment. Expert knowledge is required throughout the data stream from collection to indicator interpretation. Many additional data sources could contribute to MPs in the NS, e.g., fine-scale data could augment analysis and interpretation. The process of extending and combining existing monitoring should focus on objectives and data quality-the original objective of any on-going MP, and its value as an ecological time series should be retained. A focus on objectives (i.e., robust data support for MSFD indicators) highlights the priority of endpoint comparability over sampling methodology. MSs must produce outputs that support subregion-scale assessment of GES, but need not arrive at these outputs using exactly the same monitoring approaches. Modifying or extending an on-going MP demands many of the same value and data-quality considerations as designing a new MP.

Improved interaction between MSs: The MSFD provides a strong incentive for EU MSs to discuss and align their monitoring practises, data collection and analysis between scientists and monitoring managers. More regular and active co-ordination could address general challenges in data analysis and reporting. The workshop developed case study JMPs through open discussion framed around a series of questions (Table 1). In the future, these questions might provide the basis of a decision tree that could be used in the development of MPs to ensure data comparability across MSs and hence robust GES assessment at MSFD subregion-scale.

Dedicated interaction among stakeholder groups: The MSFD will require dedicated communication between stakeholders to ensure that decisions are based on sound science and coherent policy direction. There are many strategies and tools in place that can be adopted to ensure transparency and to ensure knowledge is cascaded between sectors – the optimal form of stakeholder interaction for the MSFD must be identified [21]. Examples of successful stakeholder interaction for integrated monitoring can be seen in the Irish Sea [22].

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