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Report of the Workshop to plan an integrated monitoring Programme in the North Sea in Q3 (WKPIMP)

22-26 February 2016

ICES HQ, Copenhagen, Denmark

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Executive summary

The workshop to plan an integrated monitoring programme in the North Sea in Q3 (WKPIMP) met on 22-26 February 2016 at ICES HQ, in Copenhagen, Denmark.

Integrated data collection means that the data collected relate to each other, and that the set of data collected adds value to the separate components. Integrated data collection may save more time and/or money and/or provide more information for the same amount of money than only improved coordination of data collection.

The workshop delivered a proof of concept for an integrated survey in the North Sea in Q3, to be considered as part of a wider North Sea ecosystem monitoring programme. It should be realized that a single survey, irrespective of whether it is single or multi vessel, is unlikely to lead to a fully integrated monitoring programme. Consequently, for practicality reasons, not all ecosystem components would be covered under the proposed survey.

The plan takes into account the data collection for current data end-users (mainly fish stock assessment groups using the GOV catch and age data), as part of the integrated data collection, as well as the processes in the ecosystem components related to the demersal ecosystem.

The relevant processes are:

- Foodweb relations from primary production to fish (via phytoplankton and/or macrobenthic in- and epifauna);
- Effect of physical-chemical environment on the biota; temperature, salinity, suspended particulate matter, humic acid, and oxygen;
- Relation demersal fish/macrobenthic fauna and sediment;
- Life cycle herring and sprat.

The general objective is to assess ecosystem processes as relevant to the demersal ecosystem and to human usages of that system. Below this general objective, detailed objectives have been defined.

The survey will have a stratified random design, the strata definition based on the definitions from the EU project 'Towards a Joint Monitoring Programme in the North Sea and Celtic Sea'. Stations will be picked randomly within the stratum, based on safe sampling locations. The first few will be all purpose stations, i.e. high priority to collect all sample types. For those ecosystem components needing more samples or better representation additional randomly picked stations should be added within the strata.

1 Administrative details

The workshop to plan an integrated monitoring programme in the North Sea in Q3 (WKPIMP) met ob 22–26 February 2016 at ICES HQ, in Copenhagen, Denmark. The meeting was attended by seven participants. One participant joined for a presentation on Monday. On Friday morning, the proof of concept was presented to representatives from the International Bottom Trawl Survey Working Group (IBTSWG), two staff members of ICES Secretariat, and the ACOM chair, using Skype for business. The list of participants is in Annex 1, the agenda in Annex 2.

2 Introduction

Important drivers for seeking new collaborations are i.e. the requirements of the Marine Strategy Framework Directive (MSFD), both in terms of increased number of parameters that contribute to the assessment of Good Environmental Status (GES) and the need for coherence between EU Member States. For the Common Fisheries Policy (CFP) increased understanding of ecosystem processes is needed for stock assessments. Moreover, monitoring budgets in many countries are under pressure. Hence, both fisheries and environmental monitoring managers seek ways to increase the (cost)efficiency of their programmes.

2.1 Ecosystem monitoring

Integrated data collection means that the data collected relate to each other, and that the set of data collected adds value to the separate components. Integrated data collection may save more time and/or money and/or provide more information for the same amount of money than only improved coordination of data collection.

The Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR) (ICES, 2016a) demonstrates that there are different pathways towards ecosystem monitoring, depending on reporting requirements and budgets. Three entry points for the collection of a wide range of marine ecosystem data are presented: (a) development of a new integrated ecosystem monitoring programme, (b) modification of existing monitoring programmes/surveys to collect ecosystem information, and (c) adding data collection to an existing survey or monitoring (Figure 2.1.1). The suitable option depends on a number of factors, e.g. the monitoring objectives, the scope for adapting current objectives, and existing monitoring programmes with tasks that have to be carried out in future. In addition, the multiple levels of management (international, national, and local) with overlapping/variable scales of requirements and interests (e.g. fisheries, biodiversity) play a role.

More guidance on integrated ecosystem monitoring can be found in Section 8.

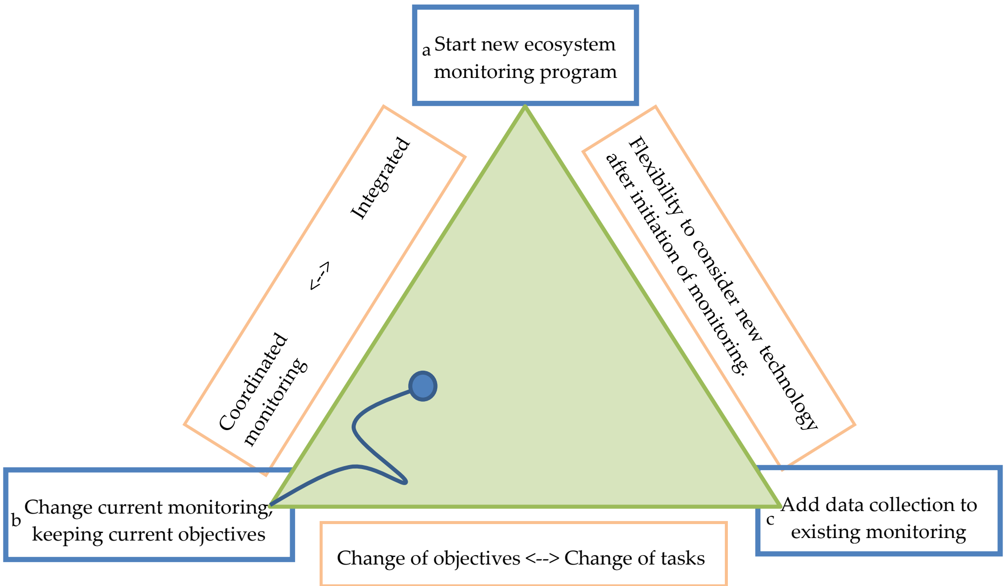


Figure 2.1.1. The continuum of ecosystem monitoring planning developments. Blue boxes (a, b, c): entry points. Example path (blue line and dot) shows the iterative development of the optimal solution through the considerations of the framework flexibility constraints and technical analytical considerations. (ICES, 2016; in prep)

2.2 Workshop approach

The entry point (Figure 2.1.1) chosen for WKPIMP was (b) Change current monitoring while keeping the current objectives as part of the total set of objectives.

The workshop was carried out using the stepwise approach as proposed by WGISUR 2015 (Annex 3, outline in Figure 2.2.1).

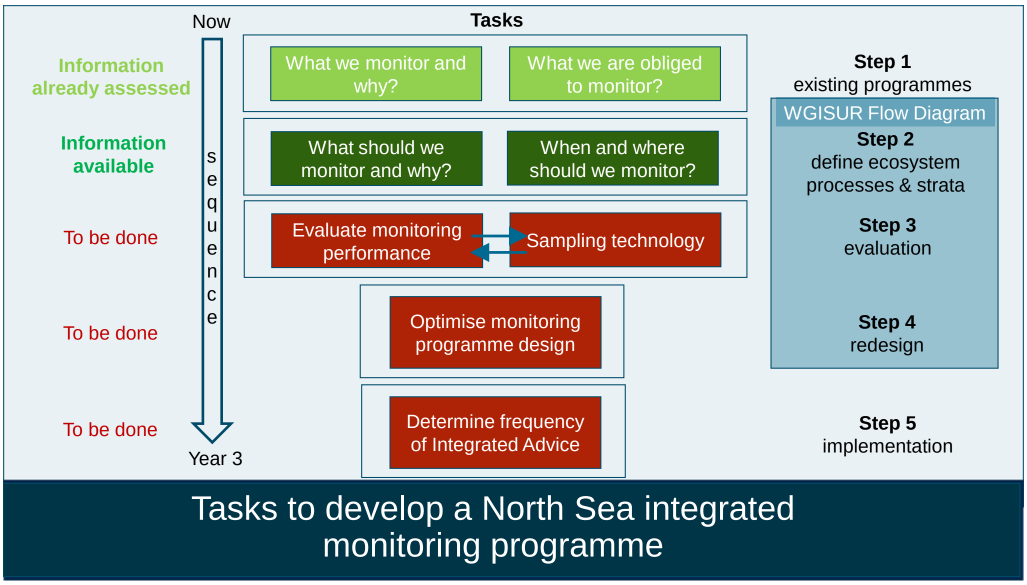


Figure 2.2.1. Scheme of approach used during WKPIMP.

2.3 Document structure

The workshop delivered a proof of concept for an integrated survey in the North Sea in Q3, to be considered as part of a wider North Sea ecosystem monitoring programme (Section 3).

The (scientific and practical) reasoning for the proposed data collection is in Section 4.

The data collected, time frame, number of ship days and other details on the current IBTS Q3 in the North Sea are in Section 5.

3 Proof of concept for an integrated ecosystem survey in Q3 in the North Sea

The proof of concept presented below provides the following opportunities:

- Linking up different monitoring by providing coordinated and integrated information;
- Provide information to models;
- Provide information to habitat maps.

It should be realized that a single survey, irrespective of whether it is single or multi vessel, is unlikely to lead to a fully integrated monitoring programme (ICES 2012, WKECES). As a consequence, for practicality reasons then not all ecosystem components would be covered under the proposed survey. We therefore focus here on the components that are most appropriate to sample along with the fish component, but considering where other components could be sampled. The principles used here could however be extended towards a complete North Sea ecosystem monitoring programme.

3.1 Ecosystem components to measure

As the plan should also contain data collection for current data end-users (mainly fish stock assessment groups using the GOV catch and age data), as part of the integrated data collection, the processes in the ecosystem components related to the demersal ecosystem should be monitored.

The relevant processes are:

- Foodweb relations from primary production to fish (via phytoplankton and/or macrobenthic in- and epifauna);
- Effect of physical-chemical environment on the biota; temperature, salinity, suspended particulate matter, humic acid, oxygen;
- Relation demersal fish/macrobenthic fauna and sediment;
- Life cycle herring and sprat.

The parameters to be measured and the sampling methodologies are listed in the first two columns of Table 3.4.1 (Section 3.4). More background on ecosystem processes in the North Sea can be found in section 4.

3.2 Objectives

The general objective is to assess ecosystem processes as relevant to the demersal ecosystem and to human usages of that system

Below this general objective, detailed objectives have been defined.

Ongoing objectives (see Section 5.2 for detailed information):

- Provide time-series for stock assessments as carried out by HAWG[1] (sprat), WGNSSK[2] (roundfish), WGWIDE[3] (horse mackerel), herring/sprat in 3a, WGEF[4] (elasmobranchs);
- Provide information on seafloor litter;
- Provide information for the OSPAR Large Fish Indicator (LFI).

New objectives (see Section 7 for detailed information):

- To improve data collection for the ongoing objectives;
- To collect new data for understanding the processes as relevant to the demersal ecosystem and to human usages of that system.

One of the opportunities of this integrated ecosystem survey is that it could link up different monitoring by providing coordinated and integrated information, especially when different monitoring techniques are being used by e.g. two countries for similar types of information. See for example Table 3.2.1 (infauna and sediment sampling).

Table 3.2.1. Comparing the new IBTS Q3 sampling to existing national sampling in marine and coastal waters in North Sea countries for infauna and sediment sampling.

	Integrated ecosystem survey Q3	MSFD	WFD
Area	Offshore marine	Marine + Coastal	Coastal (+ 12 Nm Hazardous)
Coordination	International	Patchy, not implemented	National
Species (infauna)	X		X
Abundance (infauna)	X		X
Sensitivity (examples)	Trawling	D5, D6 (infauna sampling) D8 (sediment sampling)	OM, O2
Biomass (infauna)	X		
Sampling gear; Macroinvertebrate Infauna sampling	ICES agreed, e.g. Hamon grab; Box corer; NB: stable in rough weather, deep-water, coarse sediments	Various devices	Nation/regional e.g. Day grab van Veen Smith McIntyre
Sediment sampling	Core samples; Box corer (subsample)		Core samples; Box corer (subsample)
Station design	Random within trawl haul area. Replicated if needed.	Fixed for temporal trends; mostly nationally organized Some countries: additional random sampling for spatial trends.	Single sample at fixed replicated each assessment cycle (every 1, 2, and 3 years)

[1] Herring Assessment Working Group for the Area South of 62°N (HAWG)
[2] Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
[3] Working Group on Widely Distributed Stocks (WGWIDE)
[4] Working Group on Elasmobranch Fishes (WGEF)

3.3 Strata definition

The strata definition is presented in Figure 3.3.1 The basis for strata definition used is the map created in the EU project 'Towards a Joint Monitoring Programme in the North Sea and Celtic Sea' (JMP NS/CS), originally based on the Atlantis model(Sell *et al.*, 2015). The areas not sampled in the current Q3 area were excluded, which represents mainly the coastal areas, the Norwegian deep and the shelf edge in the north. Based on expert judgement, it was decided to split up the Orkney/Shetland North stratum into two strata and separate the Fladen ground from the rest of the stratum. Detailed information on strata in the North Sea can be found in Sections 4.2.2, 4.3, 4.4 and 8.2.

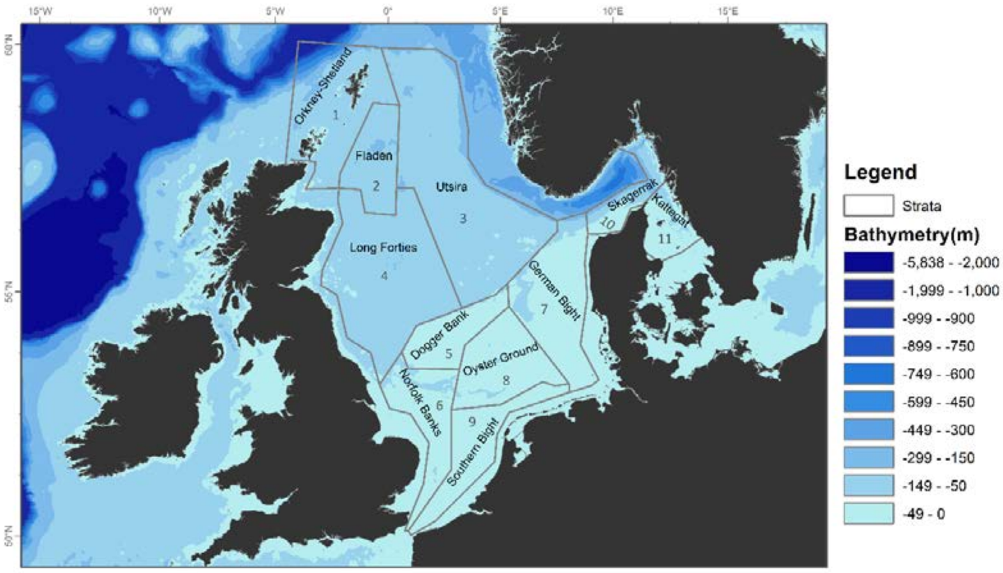


Figure 3.3.1 Adapted strata map used by WKPIMP (ICES, 2016c)

3.4 Sampling effort

Stations will be picked randomly within the stratum, based on safe sampling locations. The first few will be all purpose stations, i.e. high priority to collect all sample types. For those ecosystem components needing more samples or better representation additional randomly picked stations should be added within the strata. So although not all components are collected at all stations, the total number of stations is determined by the maximum number of samples required for a single component.

An arbitrary number of 10 stations per stratum was chosen as a starting point, but this starting point was modified based on an understanding of the variability of the specific processes that occur in that stratum in relation to the various ecosystem components. Dependent on requirements the relative proportion of stations (Table 3.4.1) can be raised to attain a given level of ecosystem monitoring precision.

Table 3.4.1. Relative sampling effort by stratum and component (N/A: component not considered relevant to the ecosystem process in the specific stratum)

Methodology	Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
GOV	Fish	11%	9%	11%	11%	7%	11%	7%	7%	7%	11%	7%
GOV	Litter seafloor	7%	7%	7%	7%	11%	11%	11%	11%	11%	11%	7%
GOV/2 m bt/BTS	Macrobenthic epifauna*	11%	11%	11%	11%	11%	11%	5%	5%	5%	11%	11%
Grab	Macrobenthic infauna	9%	5%	40%	13%	3%	4%	9%	5%	4%	5%	3%
Grab	Sediment	12%	6%	18%	12%	6%	6%	12%	6%	6%	12%	6%
MIK	Gelatinous zooplankton	8%	8%	13%	13%	8%	8%	8%	8%	8%	8%	8%
MIK	Large fish larvae (herring, sprat)	12%	12%	18%	N/A	N/A	N/A	12%	12%	12%	12%	12%
NISSKIN bottle	vertical phytoplankton sample	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%
NISSKIN bottle	Humic acid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100%
vertical CTD	vertical temperature profile	10%	10%	10%	10%	7%	7%	7%	7%	7%	13%	13%
vertical CTD	oxygen profile/bottom oxygen	N/A	N/A	N/A	N/A	43%	N/A	N/A	N/A	N/A	N/A	57%
vertical CTD	SPM	N/A	N/A	N/A	N/A	12%	12%	15%	15%	15%	15%	15%
vertical CTD	vertical salinity profile	N/A	N/A	N/A	N/A	11%	11%	11%	11%	11%	22%	22%
WP2	vertical zooplankton sample	8%	8%	13%	13%	8%	8%	8%	8%	8%	8%	8%

***it should be investigated to which extent the GOV provides sufficient information for macrobenthic epifauna, and if the beam trawl survey in the North Sea in August-September can provide additional/more detailed information.**

Next to this station-based approach, data from continuous recordings should be used. It is advised to do continuous underway measurements for at least surface temperature, surface phytoplankton, surface zooplankton, suspended particulate matter (turbidity; fluometry) and collect information on the seabed (e.g. multibeam). Combining the continuous (often surface-related) information with station related data lead to improved spatial information. Sections 3.6.1 and 6.2 describe potential continuous underway sampling methodologies.

3.5 Sampling design

3.5.1 Station-related sampling design

The survey will have a stratified random design based on a large list of safe sampling positions for GOV and other sampling gears. For infauna it is recommended to use multibeam information to check if it is possible to take a grab at a certain position.

To create as much ecosystem overview for the North Sea as a whole, and prevent bias within strata on a country basis, it is advised that:

- Each stratum should be sampled by multiple countries each year sharing the sampling effort;
- Currently the IBTS is performed with the intention of having two research vessels operating in each of the ICES rectangles to reduce vessel effects. Vessel effects could arise from differences attributed to the ship, modifications to sampling gears, and to differences in how the sampling protocol is executed. The degree of overlap in sampling areas has to be weighed against the amount of time/money spent steaming between stations. For the proposed integrated monitoring programme calibration among countries could be achieved by dividing the sampling effort in each strata between at least two countries (Table 3.5.1.1);
- Countries should sample multiple strata in order to disentangle possible year and ship effects in the sampling design;
- Sampled strata could vary by country on a year-by-year basis; in doing so, it improves the decoupling between ship and stratum effects and allows for the testing of interactions between the two. In addition, by sampling in multiple strata in a year and in different strata over years, a broader ecosystem understanding will be created on board.

By introducing an alternating two-year schedule (even and odd years) strata could be sampled by more countries without increasing the amount of time spent steaming between stations. The exception is stratum 11, which is suggested to be sampled by Sweden only for logistic reasons. The Swedish platform could however be compared to that of other countries in stratum 10.

A programme for regular exchange of staff should be initiated to ensure that sampling methods and procedures are standardized/harmonized.

Additional information on spatial sampling designs is in Sections 8.2 and 8.3.

Table 3.5.1.1. Example of relative sampling effort by stratum and country in an alternating sampling scheme (red bold: strata sampled in all years by the country; black: strata sampled in either the odd or the even year)

YEAR TYPE	COUNTRY	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	N STRATA BY COUNTRY
Odd	Norway	0.5	0.5	**0.5**									3
Odd	Scotland	**0.5**	**0.5**	**0.25**	0.5								4
Odd	England				**0.5**	0.5	**0.5**			**0.5**			4
Odd	Germany			0.25				0.5	**0.5**	**0.5**			4
Odd	Denmark					**0.5**	0.5	**0.5**	0.5		0.5		5
Odd	Sweden										**0.5**	**1**	2
N countries per stratum		2	2	3	2	2	2	2	2	2	2	1	
Even	Norway			**0.5**				0.5	0.5		0.5		4
Even	Scotland	**0.5**	**0.5**	**0.25**									3
Even	England	0.5	0.5		**0.5**		**0.5**			**0.5**			5
Even	Germany				0.25	0.5	0.5		**0.5**	**0.5**			5
Even	Denmark			0.25	0.25	**0.5**		**0.5**					4
Even	Sweden										**0.5**	**1**	2
N countries per stratum		2	2	3	3	2	2	2	2	2	2	1	

3.5.1 Continuous underway samples

Where possible, continuous underway measurements (e.g. temperature, phytoplankton, zooplankton and benthic habitats) should be collected as this will allow the extrapolation of the processes quantified to be applied at the regional level and therefore enlarge the spatial scale of all the information. To use resources as efficiently as possible, automated sample collection/analysis systems (e.g. ferrybox, flowcytometer, LIZA/PIA systems and OLEX) should be preferred, to sample storage and post-cruise manual analysis.

It should be encouraged to grab the opportunities for testing new underway sampling techniques and/or automated sample processing.

3.6 Sampling techniques and sample analysis

For fish (GOV), CTD and oxygen profiles and water samples (NISSKIN bottles) there is little evidence that these methods are not appropriate. So for consistency with historic data these methodologies should be retained unless there are specific incompatibilities with other types of equipment or aims.

3.6.1 Zooplankton

There are two aspects to consider for the collection of zooplankton data: the way the samples are collected and the way these are analysed.

3.6.1.1 Sample collection

There are many ways to collect zooplankton sample. It is impossible to collect a sample that is representative of the entire zooplankton compartment as zooplankton vary in size from the micro- to the large jellyfish, and their distribution can vary along both horizontal and vertical scales. The method chosen depends on the question to answer and the zooplankton fraction needed to answer that question. The following methods are considered bearing in mind that the idea is to fill the gaps left by other existing monitoring programs in the North Sea such as the CPR. The CPR is fairly efficient at retaining copepods but gelatinous plankton are poorly sampled and fish larvae have not been analysed since after 2005.

- Use of underway continuous sampling: this method collects samples at a fixed depth (~ 5 m) along a selected transect as the ship sails:
  - No need to deploy any gear;
  - It can be stopped and started at any time;
  - It can be combined with automated image analysis (PIA-Liza);
  - Limitation include: lack of column sampling, damage to fragile organisms (such as gelatinous plankton) is possible as a result of the pump system.
- Use of vertical deployment of nets: this method is limited by the size of the ringnet as well as the mesh size used. A common net is the WP2 (0.5 m diameter with 200 μm mesh):
  - Best adapted for the mesozooplankton fraction (copepods generally fall within that range);
  - Not so good for larger organisms such as gelatinous plankton. For gelatinous plankton a WP3 net (1 m diameter, 1 mm mesh size) is recommended. Deployment of the two nets can be done simultaneously. This however results in two samples and consequently a doubling in analysis time required.
- MIK net (2 m diameter, 3 mm mesh size) deployment: this is done in an oblique trawl and therefore needs to be towed by the ship.
  - Sample the entire water column;
  - Target fish larvae;
  - Good at retaining gelatinous plankton larger than 3 mm.

3.6.1.2 Sample processing/analysis

From MIK samples gelatinous zooplankton should be sorted straight away and the larvae should be conserved following the existing protocol for the IBTS Q1 MIK sample processing.

For other zooplankton samples, the use of onboard optical image analysis is recommended whenever possible for the following reasons:

- There is no need to preserve the samples in formalin to be taken back to the lab;
- All organisms are measured;
- Automated analysis is quicker than using the microscope, saving time on analysis. However, it is important to bear in mind that the need for a human operator is not removed. Images need to be validated. As a rough in-

dication, an experience taxonomist should be able to go through the validation of 5–8 samples per day (as opposed to about 2 samples if a microscope is used).

- When there is a taxonomist available to validate the identification done by the software, it is possible to have data ready to use at the end of the survey, rather than a set of samples preserved in formaldehyde that still need to be processed in the laboratory. This of course depends on the number of samples collected and that need to be processed.

Two systems capable of analysing zooplankton onboard exist:

ZooCAM is a new instrument, developed by Ifremer (France), to count and classify eggs and mesozooplankton. ZooCAM uses the same plankton identifier software as ZooSCAN (i.e. ZooProcess), thus offering the same standardization of enumeration, sizing and identification methods.

LiZA/PIA system (Line-scanning Zooplankton Analyser/Plankton Image Analyse) is a real-time high-speed instrument developed by the University of Plymouth that continuously takes samples from the seawater drawn from the ship's seawater supply collected at a fixed depth, while underway. In that respect, it is similar to the CUFES. However, the LiZA/PIAsystem combines automated sampling with automated analysis (counting, sizing) and taxonomic classification of images of zooplankton (similar to ZooScan and ZooCAM), embedded in an all-in-one design.

The system can process and analyse 600–1200 litres of water per hour continuously, to a specimen resolution of 100 µm, with minimal human effort. Development of the LiZA/PIA is ongoing and once a comprehensive training set for machine-learning has been compiled, analyses could be completed in real time in the near future.

There is currently some ongoing communication between Cefas (Sophie Pitois) and the University of Plymouth (Phil Culverhouse) for testing the LiZa/PIA on the RV Cefas Endeavour in October 2016. This system can also be used in an off-line configuration to analyse samples collected by other means, e.g. vertical net samples, similarly to ZooCAM.

3.6.2 Macrobenthic infauna and sediment

Information on the optimal sampling times and sites as well as the number of stations for macrobenthic infauna and sediment sampling can be found in Annex 5.

3.6.2.1 Sample collection

Infauna and sediment sampling in the North Sea should be conducted using robust and reliable methods, such as Hamon grab or box corer. Stability is important especially in rougher sea conditions and in deeper areas (> 50 m). More information on the most suitable sampling device can be found in Rumohr (2009).

Sediment sampling can be performed with any comparable method to get enough material from a specified sedimentary layer. (e.g. for grain size 0–5 cm) for being analysed according to a lab standard method.

3.6.2.2 Sample processing/analysis

It is recommended to follow the guidelines as mentioned in Rumohr (2009) for sample processing and analysis.

3.6.3 Oxygen

Oxygen sampling in Kattegat is crucial due to its oceanographic features with high productivity in surface waters, current stratification with brackish Baltic Seawater on top of limited bottom-water volume. This increases the sensitivity for oxygen deficiency or anoxia due to sediment redox processes, organic matter decomposition (microbial) and organism respiration. Low concentrations of dissolved oxygen in the water close to the seabed indicate oxygen deficiency or anoxia. Low concentrations can occur as a result of decomposition of excess organic material produced by algae (phytoplankton) or macroalgal communities during their growing seasons, are an indirect effect of nutrient enrichment. Other factors which may influence oxygen levels include water temperature and salinity, and the impacts of climate change.

Low oxygen levels may result in increased abundances of species, which are able to tolerate low oxygen conditions. Very low concentrations of oxygen may result in death of marine animals, particularly those which are unable to escape and/or are exposed to prolonged periods of very low oxygen availability (partly copy pasted from OSPAR Assessment sheet).

3.7 Opportunities for collaboration

As a complete ecosystem monitoring cannot take place in one survey, even not when it is carried out by multiple vessels, Table 3.7.1 lists potential additional data collections may be considered in addition to the Q3 sampling as described in this report, to increase the amount of ecosystem information in Q3 in the North Sea.

Table 3.7.1. Opportunities for other sources of information from research cruises (see also Section 6.1).

Parameter	Methodology	Platform/survey/...
Marine mammals	Visual observation	Herring acoustic survey July
Seabirds	Visual observation	Herring acoustic survey July
Acoustic mackerel/horse mackerel observations	Acoustic devices	Herring acoustic survey July and/or Herring larvae survey September
Macrobenthic epifauna (see also Section 3.4)	Beam trawl (2 or 8 m)	Beam trawl survey August/September

Apart from more station/transect-based information, data from external sources (e.g. satellite images) can improve understanding of the processes and help to groundtruth station-based information. For example, for chlorophyll information ocean colour observation by satellites (i.e. the new EU Copernicus programme and precursors) and remote sensing data would enhance the spatial and temporal coverage while being less costly that ship based monitoring. Next to that, *in situ* sampling for calibration purposes remains needed but with less effort than the current national programmes. Section 6 elaborates on the potential additional data sources.

3.8 Setting priorities

Fieldwork at sea is sensitive to unforeseen circumstances such as bad weather and technical breakdowns. First of all, it is advised that where possible replacement gears and spare parts should be carried on board. However, when the weather is (too) bad or technology (partly) fails, sampling priorities should be:

1) Proportionally direct effort to cover all strata agreed to sample. It is more important to collect information from all strata than to sample all stations in one stratum and no stations in another.
2) Obtain stations with a full integrated sampling. It is important to collect all data on the stations as the sampling is designed to provide information on processes, and not on status.
3) Samples that critically affect the use of other samples. When it is not possible to sample specific parameters (e.g. as a result of technical problems or because some gears are more sensitive to rough conditions than others), decide what parameters critically affect the utility of estimates of other parameters. An oversimplified absolute example might be wanted to measure salinity. We tend to measure this as a function of conductivity and temperature. Without a reliable measure of temperature, there is no point in collecting conductivity information. If we could produce reliable predictions of temperature form say models or satellites, then there may be some point in collecting conductivity, but the value would be decreased conditional on the reliability of the temperature estimates.
4) Relative information content and the future.

3.9 Make data available

To be able to use the data as good as possible, all data should be made available as soon as possible after the survey, taking into account sampling processing time, quality checking, etc. For a number of data types databases are available at ICES (Table 3.9.1).

Table 3.9.1. Databases at ICES by parameter

Parameter	ICES database
Fish	DATRAS (datras.ices.dk)
Litter seafloor	DATRAS (datras.ices.dk)
Macrobenthic epifauna (from GOV)	DATRAS (datras.ices.dk)
Macrobenthic infauna	
Sediment	
Gelatinous zooplankton	
Large fish larvae (herring, sprat)	Eggs and larvae database (eggsandarvae.ices.dk)
Vertical phytoplankton sample	
Humic acid	
Vertical temperature profile	Hydrographic database (ocean.ices.dk)
Oxygen profile/bottom oxygen	Hydrographic database (ocean.ices.dk)
SPM	Hydrographic database (ocean.ices.dk)
Vertical salinity profile	Hydrographic database (ocean.ices.dk)
Vertical zooplankton sample	

3.10 Survey coordination

If this proof of concept is going to be put into practice, it should be considered to coordinate the integrated monitoring regionally rather than by ecosystem component/monitoring gear.

It is important to realize that few people have the experience of conducting fully integrated survey, so support/feedback in decision-making is helpful. Regional coordination will certainly facilitate knowledge exchange. Furthermore, a contact person ashore to coordinate/support during sampling will increase the chance to fully carry out the survey as planned as oversight of the ecosystem monitoring programme could provide advice at short notice, while the survey is at sea

3.11 Next steps in near future

3.11.1 Things to be done

Refinement of the proof of concept is still necessary. There is a few things that need to be done to guarantee that the newly proposed setup won't create loss of time-series, although it may be necessary to recalculate the current time-series. WKPIMP recommends that the following topics are investigated:

- Analyse the effects of a new design on the precision of the used stock indices (WGISDAA[5] in collaboration with IBTSWG);
- Analyse vessel/country effects in the fish age data (WGISDAA in collaboration with IBTSWG);
- Compare the macro-epibenthos catches in species composition and quantity of at least IBTS Q3 and Beam Trawl Survey catches (WGBEAM[6] in collaboration with IBTSWG;
- Identify criteria for output quality of new end-products (end-users)

3.11.2 Improving the proof of concept

The proof of concept will be reviewed by IBTSWG 2016. This group should be able to:

- refine the allocation of stations over the countries (Table 3.5.1.1);
- decide if there is opportunity to run the proposed devices on all vessels;
- decide on the impact on the capacity needed on all vessels.

For most MSFD descriptors data can be collected within this survey, although not always on the appropriate scale for all descriptors. That should in itself not lead to problems when the evaluation of GES for the descriptor does not solely depends on this monitoring at sea.

Annex 3 contains the full action list to move from the current proof of concept to an integrated survey.

[5] Working Group on Improving use of Survey Data for Assessment and Advice
[6] Working Group on Beam Trawl Surveys

4 Understanding ecosystem processes in the North Sea

4.1 Environmental context

The North Sea is one of the most productive, intensively exploited and studied marine ecosystems in the world. It is a large shelf sea marine ecosystem influenced by large annual and seasonal fluctuations in fluxes of deep Atlantic water mixing with cold Arctic currents in the northern North Sea, whereas the southern North Sea is dominated by coastal water masses significantly influenced by inflow of freshwater, nutrients and other substances from several major northern European river basin catchments.

The water circulation through the North Sea is generally anticlockwise, with most of the water entering in north over the North Sea plateau and exiting through the Norwegian Trench along the coast of Norway. It is relatively shallow in the southern and central sectors (30–40 m), deepening to > 100 m in the northern sector, with depths > 700 m occurring in the Norwegian trench adjacent to the Norwegian coast.

4.2 Trends

Assessments of North Sea pressure/state data conducted by WGINOSE[7] (ICES, 2014) and more recently by an EU FP7 project BENTHIS describe important temporal and spatial gradients in the North Sea ecosystem.

4.2.1 Temporal trends

An analysis of the available North Sea time-series data (1983–2009) reveals a number of shifts in state, e.g. rate of change in the North Sea ecosystem, with some groups of years having greater similarity than others. This is shown in Figure 4.2.1.1, which also highlights a number of 'key' signals such as: sea temperature, zooplankton and pelagic fish length which demonstrate strong trends over time.

[7] Working Group on Integrated Assessments of the North Sea

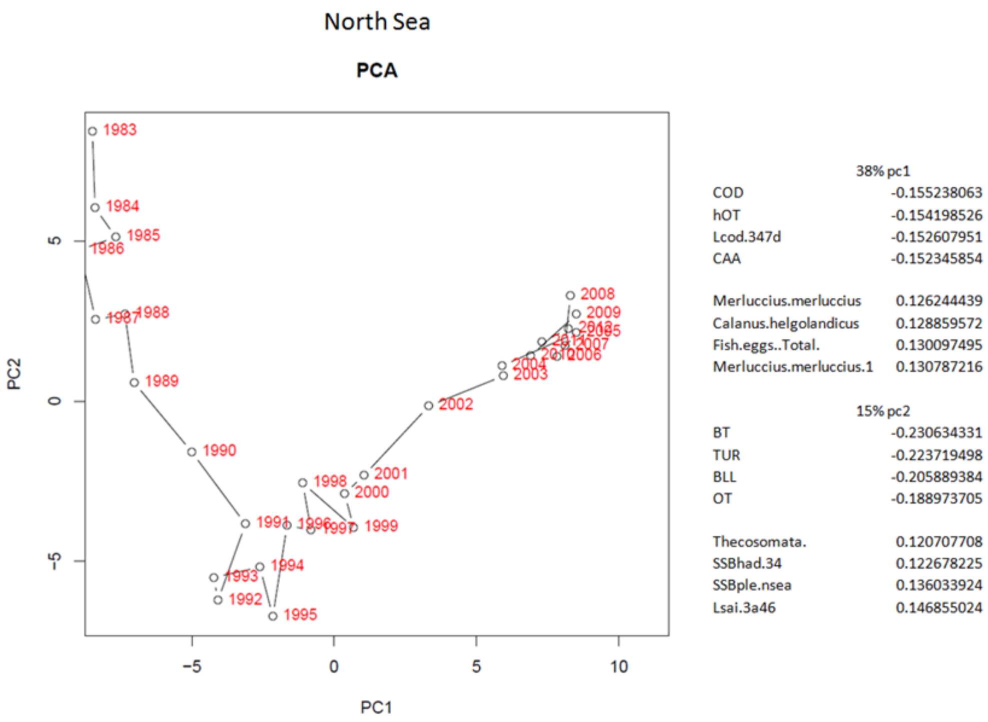


Figure 4.2.1.1. PCA of all state/pressure variables for the North Sea, COD = cod cpue, hOT = hrs otter trawling, Lcod374d = cod landings, BT = beam trawl effort, TUR = turbot cpue etc.

4.2.2 Spatial trends

4.2.2.1 Macrofauna

In 1986 a wide-scale benthic survey of the North Sea was coordinated under the auspices of ICES, which was repeated in 2000 (Rees *et al.*, 2007). The surveys showed a clear north–south gradient across a range of habitats in the species of molluscs, annelids, crustaceans and echinoderms, but the gradient was strongest in relation to the diversity, abundance, biomass and average individual weight of the soft-bottom infauna.

In general, the North Sea benthic macrofauna are dominated by northern species extending south to the northern margins of the Dogger Bank to, and southern species extending north to the 100 m depth contour. The central North Sea is an area of overlap of southern and northern species, especially between the 50 m to 70 m depth contours.

4.2.2.2 Plankton, fish, seabirds

Furthermore, ICES (2006) reported on the spatial patterns of plankton, fish stocks, seabird populations, which revealed significant correlations between these components (Figure 4.2.2.2.1). These in turn were closely related to the spatial patterns associated with wide scale environmental forcing through gradients in bathymetry, temperature and ocean current.

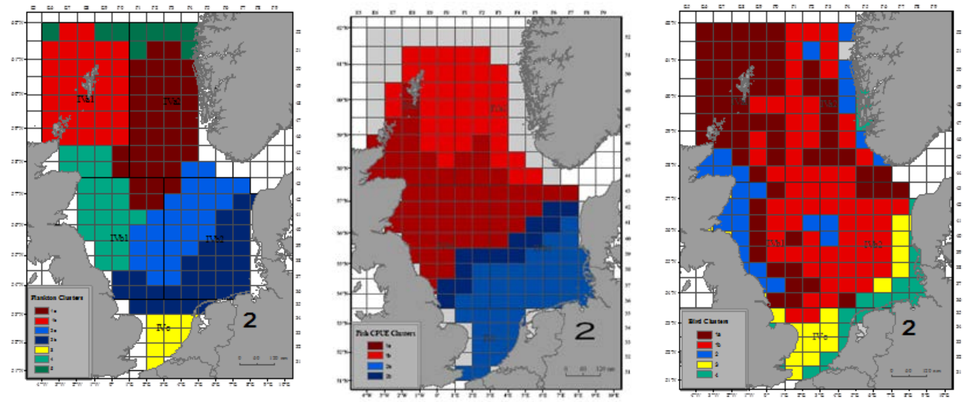


Figure 4.2.2.2.1. Cluster analysis performed on averaged North Sea plankton, fish cpue and seabird data for each ICES rectangle between 1983 and 2006 (ICES, 2006).

4.3 Functional links

4.3.1 Abiotic components in relation to benthic fauna

Among the first scientific studies describing the spatial patterns and functional links of the benthic fauna of the North Sea are those of Petersen (1913), who -working in Danish waters- explained the importance of seabed sediment type as a major force structuring macro-benthic communities.

Further studies by Glemarec (1973), examining the influence of hydrodynamic mixing of the water column on benthic communities, concluded that the thermal stability of the water column, i.e. the occurrence and persistence of stratification, was also an important explanatory variable influencing the structure of benthic communities. Depth related temperature profiles broadly matched the type of assemblages associated with the shallow mixed waters in the southern North Sea, being distinct from those in the central North Sea between 50 and 100 m deep, and also from those in the areas deeper than 100 m to the north which were more likely to be stratified for a significant period of the year.

4.3.2 Trawling in relation to biota

The type of seabed fauna has been shown to respond to both natural variation in habitat conditions and in response to different levels of fishing pressure. The extent to which different commercial fish species will depend on specific combinations of habitat type and fishing disturbance will likely be species-specific. It has been suggested that positive changes in growth rates of different demersal fish species are not only related to density-dependent processes, but may also be dependent on increased bottom-trawl disturbance and eutrophication.

Different trawling and habitat specific responses in relation to fish feeding in different size classes of fish has been investigated using biological traits analysis (BTA) of demersal fish stomach contents and habitat fauna using grab and epi-benthic trawl survey data previously analysed as part of BENTHIS.

Strong associations between community trait composition and prey consumed by the benthivorous fish (plaice) of all sizes was observed in fished shallow sand–muddy sand habitats located in the eastern North Sea and Dogger Bank. The result suggests that there is a positive association between fishing pressure and the presence of plaice in these areas. By contrast, long rough dab, haddock, cod and whiting did not appear to target fauna that was abundant in the environment within any of the habitat clusters under either fished or unfished conditions in the North Sea. These species may therefore be less affected by changes in fishing pressure on a wide range of habitats than those species (such as sole and plaice) which favour living in closer association with the benthic environment.

Secondary production was found to be highest within shallow sand–muddy sand habitat although not significantly so. Bolam *et al*. (2010; 2014) indicated that production is indeed affected by bottom disturbance, but as that affects the substratum type it is not possible to know whether this is a direct or indirect relationship with fishing pressure. Van Denderen *et al*. (2013) show that that the ecosystem response to trawling depends on whether the abundance of benthos is top–down or bottom–up controlled.

4.4 Defining strata in the North Sea

Given the strong spatial gradients in the status of the North Sea ecosystem ICES Working group on integrated ecosystem assessment in the North Sea (WGINOSE) initially focused on analysing the Northern, Southern North Sea, the eastern English Channel and the Kattegat/Skagerrak regions separately, which make up the North Sea ecoregion as a whole.

However, ecosystem models developed for the Southern North Sea region to support management advice (ICES, 2015) performed poorly. This was thought to be due to averaging over too many different subregional strata and therefore development of the models should take into account the subregional variation of defined ecologically coherent strata.

The JMP strata definition for the North Sea seems to work out well. As first analysis (ICES 2016c, in prep.) showed that strata 1–4 form a single cluster which is distinct from strata 5, 6, 8 and 9, which form another cluster. Stratum 7 appears to be a transition strata between these two dominant North/South clusters having attributes of each, whereas strata 10 and 11 (Skagerrak and Kattegat) are different yet again, but with some nice strong trends in oxygen and nutrient concentrations.

5 IBTS in North Sea in Q3

5.1 Current resources and coverage

The current IBTS Q3 is carried out annually by six vessels (from Norway, Scotland, England/Wales, Denmark, Sweden and Germany) in August and September. In total, over 300 GOV trawl hauls are carried out in approximately 125 ship days (Table 5.1.1).

Table 5.1.1. Overview of IBTS sampling effort by country in Q3 in the North Sea.

	DK	ENG	GER	NOR	SCO	SWE
Days at sea Q3	18	31	12	30	23	12
No hauls 2013	53	76	17	46	90	45
No hauls 2014	51	74	29	47	87	45
No hauls 2015	59	79	33	59	94	46

The survey covers the North Sea, Kattegat and Skagerrak (Figure 5.1.1).

The survey is mainly a daytime survey, although some countries already use night to conduct additional activities.

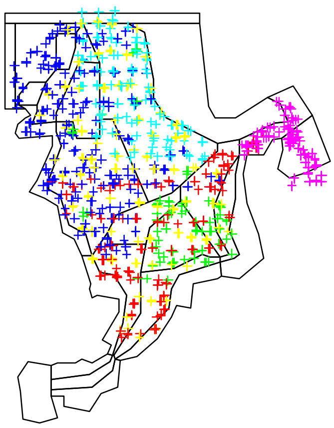


Figure 5.1.1. IBTS Q3 coverage (2015). Different colours represent countries.

5.2 Original objective and current data use

The original objective of the survey is to collect fishery-independent information for fish stock assessments. As a result, main data use is focused on the fish indices. Next to that, OSPAR is developing the large fish indicator using the IBTS Q3 as one of the dataseries, and for MSFD purposes the litter from the GOV catches is being used.

The following information is being used in fish stock assessments by ICES groups:

- sprat in IV (age, length, maturity) ; HAWG
- cod, whiting, norway pout, haddock in IV (age, length, maturity); WGNSSK
- horse mackerel in IV (age, length, maturity); WGWIDE

- elasmobranchs in IV (age, length, maturity); WGEF
- herring and sprat in IIIa (age, length, maturity); HAWG

Furthermore, for MSFD purposes, OSPAR uses IBTS Q3 information for:

- large fish indicator (existing fish data, full time-series)
- seafloor litter (new data collection)

Seafloor litter collection from GOV catches has only been implemented since a number of years, and is for that reason still under 'additional data collection' (Section 5.3).

Although information on temperature and salinity (CTD) has been collected for a long time by all countries, the data use is unclear. The CTD data have not all been uploaded in the ICES database ocean.ices.dk.

5.3 Additional information collected during IBTS Q3

Apart from sampling fish from GOV catches, other information is collected during the current survey (Table 5.3.1).

Table 5.3.1. Overview of IBTS additional data collection in Q3 in the North Sea.

Activity	DEN	ENG	GER	NOR	SCO	SWE
CTD	x	x	x	x	x	x
Seafloor Litter	x	x	x	x	x	x
Water sampler (Nutrients)		x	x	(x)	x	
Collection of fish tissues	x		(x)	x	x	x
Jellyfish from GOV catches		x		x		
Plankton biodiversity		(x)				
Epibenthos (beam trawl)			x			
Sediment (VanVeen grab)			x			
Seabirds, Marine mammals		(x)			x	
Zooplankton (MIK)				x		
Hydrological transect				x		
Acoustics (Ichthyofauna)		x		x		

6 Other monitoring in North Sea in Q3

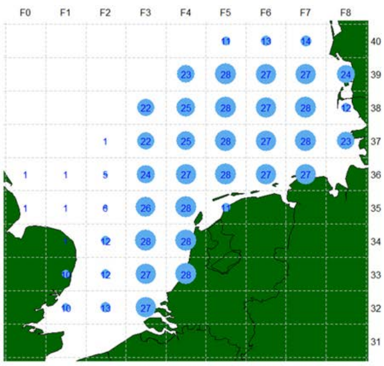
6.1 DCF monitoring

Under the EU Data Collection Framework (DCF) a number of surveys is carried out, also in the third quarter (Table 6.1.1). Those surveys may provide a better opportunity for some types of data collection than the survey described in the proof of concept.

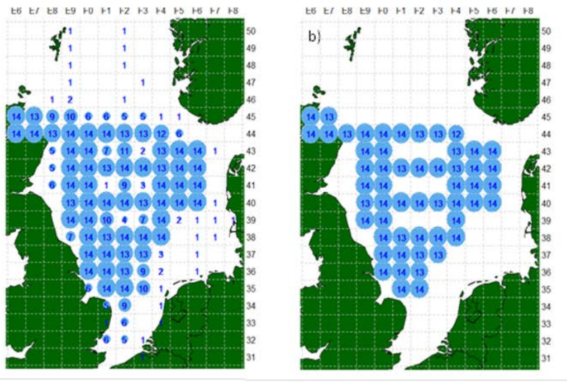
It is unclear to what extent commercial fisheries data collected under the DCF such as discard monitoring, landing statistics and VMS data in the North Sea could act as potential additional data sources. The advantage is that that data are year-round, and could in this way add information on seasonal variability.

Table 6.1.1. Overview of fisheries independent surveys funded under DCF in Q3 in the North Sea.

Survey	Primary Aim(s)	Additional information	ICES Area	Period	Sampling types
International Bottom Trawl Survey (IBTS)	Abundance indices of haddock, cod, saithe, herring, sprat, whiting, mackerel, Norway pout	Length–frequency data for all fish species, Norway lobster and Edible crab, sexratio and length–frequency for elasmobranchs, counts of macrozoobenthos, temperature and salinity	IV	Q3	Fish and plankton hauls, hydrography
North Sea Beam Trawl Survey (BTS), see Figure 6.1	Densities (abundance indices) of sole, plaice and other flatfish species	Length–frequency data for all fish species, Norway lobster and edible crab, sexratio and length–frequency for elasmobranchs, counts of macrozoobenthos, temperature and salinity	IVb, IVc	Q3	Fish hauls, hydrography
Demersal Young Fish Survey (DYFS)	Abundance indices of sole, plaice, brown shrimp	Length–frequency data for all fish species, brown shrimp and edible crab, sexratio and length–frequency for elasmobranchs, counts of macrozoobenthos (optional: temperature and salinity)	IV coastline	Sep/Oct	Fish hauls (hydrography)
Herring Larvae Survey (IHLS)	Abundance indices for herring larvae	Available in samples: other fish larvae (not always sorted)	IV, VIId	Sep	Ichthyoplankton hauls, hydrography
North Sea Herring Acoustic Survey (NHAS)	Abundance and biomass of herring and sprat	Available in acoustic profiles: information on other species (not always analysed)	IVb, IVc	Jun-Jul	Fish hauls, Echo Nm
Nephrops TV survey (FU 3 and 4)	Estimate of *Nephrops* biomass	Sea floor and bottom type information from images	IIIa	Q2 and 3	TV-tracks
Sole Net Survey	Flatfish 1/2-group abundance indices	Length–frequency data for all fish species and edible crab, sexratio and length–frequency for elasmobranchs, counts of macrozoobenthos (optional: temperature and salinity)	IVb, c	Sept-Oct	Fish hauls (hydrography)
Nephrops TV FU6	*Nephrops* abundance indices	Sea floor and bottom type information from images	IVb	Q3	TV-tracks
Nephrops TV (offshore) FU 7	*Nephrops* abundance indices	Sea floor and bottom type information from images	IVab	Q2 and 3	TV-tracks, fish hauls
Nephrops TV (inshore) FU 8-9	*Nephrops* abundance indices	Sea floor and bottom type information from images	IVab	Q2 and 3	TV-tracks, fish hauls



Sampling frequency of the Isis area from 1985-2012.



Sampling frequency of the Tridens area from 1999-2012, and b) the 54 sampling areas with a sampling frequency ≥12 years.

Figure 6.1.1. Potential surveys of macro/mega benthic invertebrates in the North Sea.

6.2 Other monitoring

There are many different types of monitoring programme in the North Sea established in response to a number of national and EU policy level drivers (e.g. Directives). However, many of these do not operate offshore or at a scale sufficient for an overall assessment of North Sea processes and state changes, e.g. inshore hazardous substances monitoring as part of the WFD. The database developed within EU project 'Towards a Joint Monitoring in the North Sea and Celtic Sea' (JMP; http://jmp.bmdc.be; username: jmpguest – password: jmpguest) contains information of many of the programmes collecting information for MSFD. To investigate to which extent national monitoring programmes could contribute to a North Sea wide integrated ecosystem monitoring programme, detailed knowledge of the monitoring is needed.

Station-based other offshore programmes include:

i. ichthyoplankton abundance, size and life stage;
ii. macro/mega benthos (Figure 6.1.1);
iii. hazardous substances including biological effects.

Continuous offshore programmes include:

i. the SAHFOS CPR zooplankton surveys which are limited to a number of sections in the North Sea that are sampled monthly (Figure 6.2.1)
ii. satellite remote sensing data (Copernicus)
iii. ferryboxes mounted on ferries and cargo ships that frequently cross the North Sea (Figure6.2.2). These ferryboxes measure chemico-physical parameters in an automated flow-through system, e.g. pCO_2, , temperature, salinity, chlorophyll *a*, nutrients. These data currently are [underrepresented/not used] in assessments under international obligations, but they certainly have the potential to contribute to the understanding of ecosystem processes.

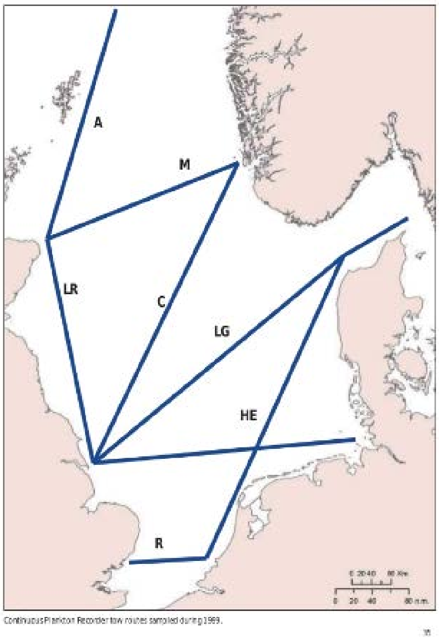


Figure 6.2.1. SAHFOS CPR plankton transects in 1999

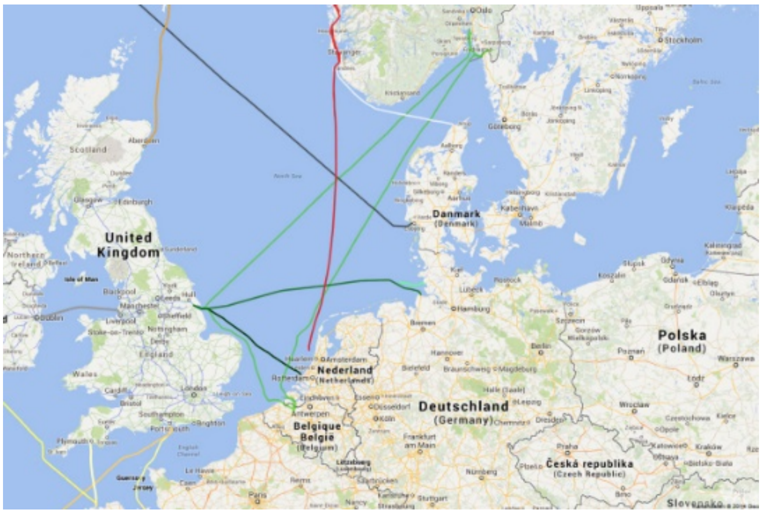


Figure 6.2.2. Ferrybox routes in the North Sea (www.ferrybox.org)

For infauna, all North Sea monitoring countries have national sampling for assessing environmental state using multimetric indices for primarily coastal waters under the WFD. These methods have also been suggested as Common indicator (MMI) within OSPAR from COBAM for assessing diversity in soft-bottom macroinvertebrate communities sampled using standard methods (ISO 16665). National multimetric methods share several similar elements reflecting the status of macroinvertebrate communities from a combination of species diversity and contribution from tolerant and sensitive species. All indices can be calculated from community composition data, but use different diversity indices and classification systems for weighting sensitive and tolerant species in the community. Biomass is not always measured or comparable among different national methods.

7 New data use requirements

Although not extensive, some end-users already specified new data requirements to either improve current data products, or better understand the underlying processes.

7.1 HAWG

- Ichthyoplankton to improve herring information (all species), useful as it is at the beginning of the herring of the spawning season. Optimal sampling gear is MIK net, time of day does not matter. Ideally, larvae sampling occurs during all autumn.
- Zooplankton sampling; covariation with recruitment strength. Currently CPR is being used, which is spatially aggregated as it is being used by ferries. Hydrodynamic models? Extend CPR data to hydrodynamic water masses as defined by hydrodynamic models. New techniques could be used to collect information on zooplankton.
- Acoustic information: herring; plankton. Acoustic information on stations/acoustic information between stations (cf. USA pollack). Aim: timing of gathering of herring.

For understanding the system, one or two years of sampling may be sufficient to test hypotheses and link the ecosystem components.

7.2 WGWIDE

- Acoustics for NS mackerel and horse mackerel

7.3 MSFD requirements

It was decided that the MSFD requirements should be taken into account in the plan as far as possible. The descriptor level was taken into account, especially because many indicators are still under development.

Descriptor 1. Biodiversity is maintained; ok

Descriptor 2. Non-indigenous species do not adversely alter the ecosystem; ok

Descriptor 3. The population of commercial fish species is healthy; ok

Descriptor 4. Elements of foodwebs ensure long-term abundance and reproduction; ok –stomach content may come in useful. Productivity may be difficult, as it is rate of change that is difficult to get directly from monitoring;

Descriptor 5. Eutrophication is minimized; nutrients in Q3 is not relevant, rest ok

Descriptor 6. The sea floor integrity ensures functioning of the ecosystem; physical disturbance only indirect;

Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem;

Descriptor 8. Concentrations of contaminants give no effects; ok

Descriptor 9. Contaminants in seafood are below safe levels; only by e.g. taking tissue samples;

Descriptor 10. Marine litter does not cause harm; ok for seafloor litter –sampling water column depends on methodology and on requirements. Floating litter -> other surveys.

Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem; not relevant measuring underwater noise from a vessel is not relevant.

Any changes in the results of monitoring need to be consistent with assessment frameworks and address the data needs of ecosystem assessments. Collaboration with groups under OSPAR that are tasked with the development of common indicators and develop assessments for the MSFD, e.g. ICG-COBAM, therefore is beneficial from a national perspective. In order to investigate current data needs for the OSPAR biodiversity indicators a 'monitoring day' was organized by ICG-COBAM (October 2015). The outcomes are reflected in a document for OSPAR's Biodiversity Committee[8]. Main monitoring needs that are potentially relevant to WKPIMP are:

a) Seabirds: need for better cooperation and geographic coverage, especially offshore;
b) Cetaceans: general lack of data, need for coordinated surveys, e.g. SCANS[9]
c) Pelagic habitats: cannot determine monitoring needs due to lack of reporting. Potential need for more offshore data next to the Continuous Plankton Recorder;
d) Fish: main data needs are for pelagic species, elasmobranchs and coastal fish;
e) Benthos: need for joint sampling design and integration with fisheries monitoring;
f) Non-indigenous species: focus on areas of introduction, but MSFD also requires information on distribution and abundance of invasive species that affect biodiversity. No budget for dedicated surveys, so sampling for other purposes will be used for monitoring the distribution [and abundance] of non-indigenous species.

Monitoring needs c) to f) were considered in the IBTS redesign as developed in the WKPIMP. It was concluded that needs a) and b) are more appropriately dealt within acoustic fish surveys, which monitor North Sea wide transects. The Q3IBTS is not considered practical for monitoring of seabirds and cetaceans because of the monitoring protocols (aimed at standardizing behaviour) currently conflict with those for fish monitoring so that they would have to be applied sequentially and therefore result in little opportunity for time savings.

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[8] BDC 16/3/4: Proposal for process towards coordinated biodiversity monitoring

[9] Small Cetacean Abundance in the North Sea and Adjacent waters (SCANS) project. Conducted twice, in 1994 and 2005. These are dedicated aerial and ship based surveys, which are considered relatively costly.

8 Guidance on integrated and coordinated monitoring

8.1 Plan development

Over the last years, the ICES Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR) has developed a number of concepts to provide guidance in ecosystem monitoring. The one most relevant in the context of WKPIMP is the flow diagram for development of ecosystem monitoring (Annex 3 and ICES, 2016a) that was taken into account for the development of plan for integrated ecosystem monitoring in the North Sea in Q3. The WKPIMP guidance is based on the flow diagram as developed by WGISUR (Figure 8.1.1 and ICES, 2012).

Figure 8.1.1. Flow diagram for the development of ecosystem monitoring (ICES, 2012)

8.2 Spatial strata and sampling design for integrated advice

WGMSFDemo is focused on investigating way of delivering the MSFD monitoring requirements for the MSFD in the Celtic Sea. A substantial part of the work has been the contribution of indicators to the 2017 assessment based on ICES data sources. Relevant to WKPIMP is the groups the work conducted reviewing the current monitoring programs and potential changes in support of the ecosystem approach that would also help deliver information to future MSFD reporting requirements.

Based on analyses for an independently developed foodweb indicator ('typical length'-TYL), the ICES Working Group to deliver MSFD monitoring requirements in the Celtic Sea (WGMSFDemo) concludes that using stratified random or systematic transect designs in conjunction with ecologically meaningful strata - developed as part of the TIME project ("Time for Truly Integrated Monitoring for Ecosystems"; joint Defra (UK) strategic evidence partnership fund (MF1231) and Cefas Seedcorn funding (DP330)) - provides significant improvements in temporal detection of change over a regional approach. Furthermore, although a significant interactive term between year and stratum suggests that there are differences in the trends for different strata, stratum specific trends are less important than the more general temporal trend. Data suggest that spatial differences are currently much greater than interannual differences with a slight increase in TYL in the western channel over the period.

Qualitative interpretation of the differences between strata in relation to fishing pressure seems to suggest that the differences are ecologically based rather than altered by fishing effort. Further analysis in respect of the ecological significance of TYL is required, particularly with regards to possible responses in TYL to changes in fishing pressure.

Because there is generally less monitoring in the Celtic Sea compared to the North Sea with fewer constraints on maintaining time-series, the group took the opportunity to examine what a fully integrated ecosystem approach could deliver with a focus on process, rather than status. Having developed a process based monitoring program it is important to understand how this might affect the status based deliverable in support of the legislative requirements for the MSFD. The group presented an analysis of the new proposed foodweb indicator 'typical length' (TYL) under development by ICG-COBAM in OSPAR (ICES, 2016b).

8.3 Spatial sampling designs for specific parameters

The EU-funded project Towards a Joint Monitoring Programme for the North Sea and Celtic Sea (JMP NS/CS; 18 institutions, 10/2013-06/2015) focused on investigating benefits and challenges of joint monitoring.

The project used the WGISUR stepwise guidance to enhance multi-use of monitoring platforms.

Further outcomes of the project can be found at the website.

The JMP NS/CS project developed examples of joint spatial designs for benthos and Elasmobranchs, thereby enhancing statistical power with the same (or less) monitoring effort, while ensuring that changes in these groups can be detected with a reasonable confidence. An important starting point is the use of common ecologically coherent strata delineated from the ecosystem model 'Atlantis' (Hufnagl *et al.*, unpublished data), which were slightly modified to reduce the number of strata (now 15 in the North Sea).

For an optimal monitoring design, multiple parameters should be combined, using the strata where possible.

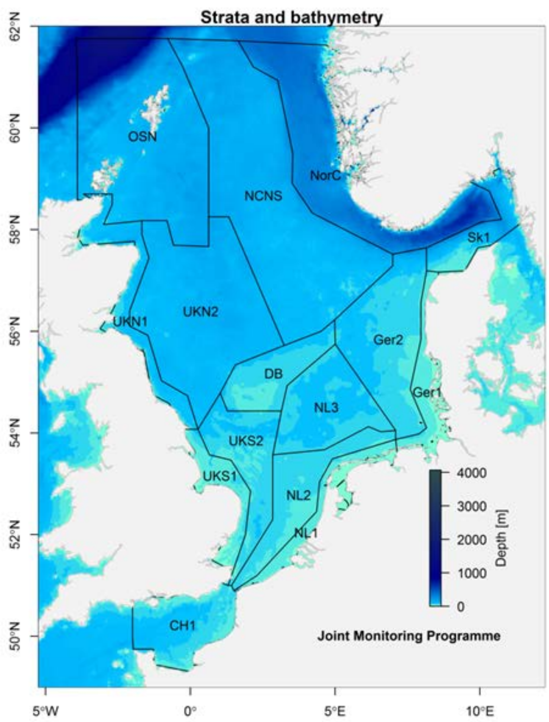

Figure 8.3.1. The 15 strata delineated from the ecosystem model 'Atlantis', and slightly modified to reduce total number of strata, overlaid with bathymetry. NL: Netherlands, UKS: UK south, UKN: UK North, CH: Channel, Ger: German strata, Sk: Skagerrak, DB: Doggerbank, NCNS: Norther Central North Sea, NorC: Norwegian Coast, OSN: Orkney Shetland North.

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Annex 1: List of participants

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Annex 2: Agenda WKPIMP (Workshop to Plan an Integrated Monitoring Program in the North Sea in the 3rd quarter)

22–26 February 2016, ICES HQ, Copenhagen, Denmark

Monday 22 February 2016

13.00 Welcome, logistics, meeting aims

13.15 Who is who?

13.30 Stepwise approach during the meeting, and how we're going to use it (Ingeborg)

14.00 Presentations on comparable studies

- Integrated assessments – understanding North Sea processes (Andy/Sven)
- EU project 'Towards a Joint Monitoring Programme in the North Sea and Celtic Sea' (finished in 2015) (Lisette)
- WGISUR work (Ingeborg)
- WGMSFDemo (Carl O'Brien/Sven)

15.00 Tea

15.30 Short presentations on end-user requirements in North Sea

- ICES HAWG (Lotte)
- ICES WGNSSK
- ICES WGWIDE
- OSPAR
- ....

16.30 Presentation of the current IBTS framework (Kai/Anne)
(should at least contain: number of vessels, spatial coverage, number of ship days, is there any downtime)

17.00 Presentation of other Q3 surveys in the North Sea (Andy/Ingeborg)

17.30 Wrap up and plan for Tuesday

18.00 End of day

Tuesday 23 February

09.00 Following stepwise approach: Problem identification and setting objectives

12.30 Lunch

13.30 Setting framework

17.45 Wrap-up, plan for Wednesday

18.00 End of day

Wednesday 24 February

09.00 Set survey objectives; develop survey design

12.30 Lunch

13.30 Identification of topics that need more attention, and work on those (maybe in subgroups)

17.15 Plenary: state-of-the-art

17.45 Plan for Thursday

18.00 End of day

Thursday 25 February

09.00 Finalize plan, and check with prior steps

12.30 Lunch

13.30 Subgroups: finalizing; including text writing, providing tables, figures, methodologies used for plan

15.00 Tea

15.30 Presentation of the plan; how to arrange?

16.30 Continue text writing, preparing presentations, etc.

17.45 Put all draft texts on sharepoint

18.00 End of day

Friday 26 February

09.00 Presentation of the plan (various people)

10.30 Coffee

11.00 Next steps

12.00 End of meeting

Annex 3: Guidance for WKPIMP

The ICES Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR) has prepared a stepwise approach for development of ecosystem monitoring in general, as well as for WKPIMP 2016 specifically (Annex 5 in WGISUR report 2015, and below).

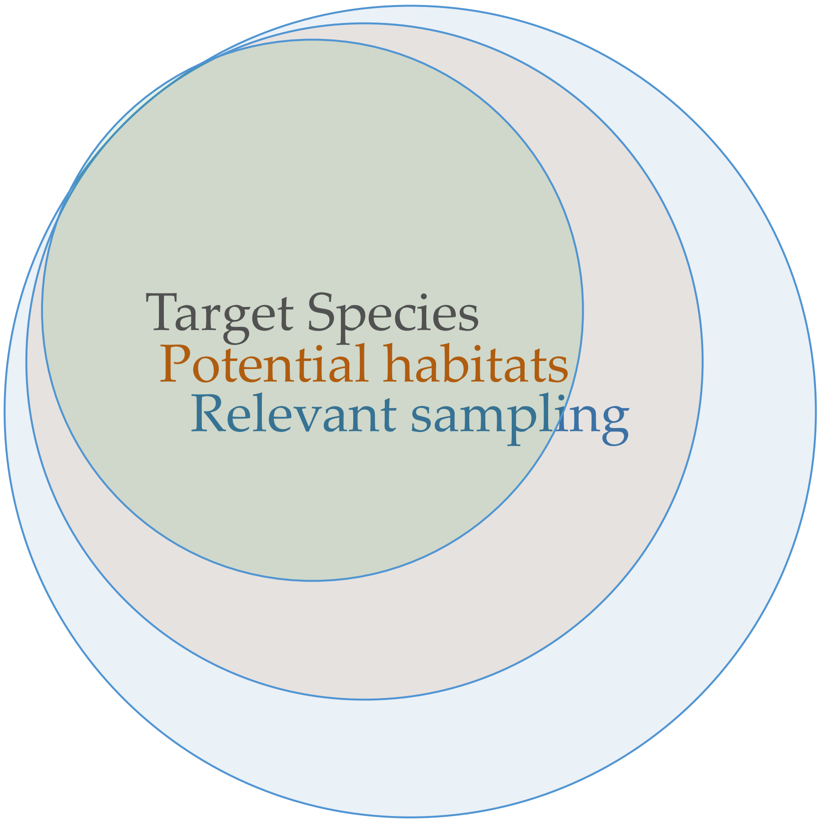
Stepwise plan for development of ecosystem monitoring

Guidance for a holistic monitoring program

A holistic monitoring program will not be developed with a single effort. Although the table below suggests that the workflow is linear, it should be clear that the creation of a plan, conducting the survey, and the use of data should be considered as an iterative process.

Spatial-temporal domains in holistic monitoring

To facilitate accurate and efficient measurements, the relevant sampling is constrained to span the management focus, e.g. the potential habitats of the target species (see Figure below).



Guidance for a Holistic Ecosystem Monitoring Program			
Steps	**Data Providers**	**Data Users**	**Advice Users**
Define target species (managed ecosystem components).	Define requisite deliverables (e.g. fishery-independent estimates of biomass) and develop hypotheses.		Assure that the stakeholders will receive the necessary advice.
Characterize potential habitats (biotic and abiotic environments and processes).	Define potential habitats using current understanding, research and models.	Assure regional or international coordination of deliverables.	
Characterize environmental and trophic interactions.	Determine the temporal-spatial importance of ecological processes to target species.		
Sample biologically relevant and optimal (or practical) spatial-temporal scales (see Figure above), with consideration to available methods (e.g. equipment, sensors, sensor platforms, and analysis techniques).	Describe the deliverables, optimal sampling plan, including the itemized cost-deliverable trade-offs (e.g. logistics, ship, personnel and skills).	Provide the resources necessary to enact the acceptable, optimal sampling plan.	
Evaluate if the improved understanding meets the objectives with the available budget.	Provide quantitative or qualitative assessment of the deliverables.	Evaluate if the deliverables meet the management requirements.	Evaluate if the management objectives would be met.
Refine and accept the plan.	*Interactively review and collectively agree.*		
Conduct ecosystem monitoring.	Monitor, test hypotheses and provide deliverables.	Evaluate the deliverables and improved understanding.	Disseminate favourable outcomes.
Periodically evaluate the monitoring program.	Evaluate the current monitoring including the cost and value of samples, collection and analysis methods and the estimated precisions of outputs.		Consider management and scientific advice and evaluate against targets.
Refine the monitoring program.	*Interactively review and collectively agree.*		

Table for guidance

WKPIMP Stepwise approach towards integrated monitoring in the North Sea during 3rd quarter

Before the steps below can be taken into account by WKPIMP, the following decisions have to be taken:

- Agreement by IBTSWG that the NS-IBTS Q3 will be used as a realistic example to modify towards an ecosystem survey, part of a North Sea ecosystem monitoring (March 2015).
- Timely announcement of WKPIMP, so all experts needed will be able to arrange attendance at WKPIMP.

	Steps	Preparation	WKPIMP
Problem identification Set survey objectives	Define target species (managed ecosystem components).	WGINOSE, WGNSSK, HAWG, WGEF	Final decision on target species/ecosystem components based on preparation; clearly defined objectives based on hypotheses. Transformation from hypothesis to objective should be based on 'does anybody care? ' (and who) Identify primary and secondary clients
	Characterize potential habitats (biotic and abiotic environments and processes).	WGINOSE, maybe in collaboration with WGECO	Final decision on habitats to be taken into account based on preparation; map with habitats
	Characterize environmental and trophic interactions.	WGINOSE, maybe in collaboration with WGECO	Final decision on interactions to be taken into account based on preparation; list with relevant interactions in Q3 in the North Sea
	Set objectives and parameters		***Define which parameters should be measured, and check if data collection meets objectives***
Set framework	Define resources and constraints	IBTSWG (current resources), WGNSSK and HAWG (constraints current objectives) WGISDAA (evaluate current sampling in relation to objectives) All: Identify other datasets available for NS Q3 (may be taken from EU overview for MSFD)	Add new objectives, check if current objectives still can be met Prioritize objectives Define minimum data requirements and variables for clients, including data quality Define precision levels for output Which information can be collected from other monitoring in North Sea in Q3 (seagoing or models, VMS data, satellite data, etc.)
Set framework Set survey objectives Survey design	Sample biologically relevant and optimal (or practical) spatial-temporal scales (see Figure in Annex 3.1), with consideration to available methods (e.g.	IBTSWG (describe current sampling, additional to the fish sampling)	Develop survey design (stratification, number of samples per sampling type, etc.); survey design should be adaptive towards future Create detailed survey plan, including definition of expertise needed, different sampling techniques and their limitations Make practical arrangements: allocate ship time, get sampling equipment, coordination during

	Steps	Preparation	WKPIMP
	equipment, sensors, sensor platforms, and analysis techniques).		the survey, etc. NB: consider that not all ships might have to carry out all sampling types.
	Evaluate if the improved understanding meets the objectives with the available budget.		Check if plan can be carried out within the current framework. If not: what should be arranged, or should the plan be modified? Check if precision levels and accuracy from sampling match the requirements Check if plan still meets objectives Define remaining shortcomings
	Refine and accept the plan.		***Present plan to IBTSWG, WGINOSE, WGNSSK, HAWG,WGEF, EU-DGENV, EU-DGMARE, ICES Secretariat***

Examples of questions that will be addressed during WKPIMP:

- Can we agree on the most appropriate scale of strata for monitoring and assessment of the North Sea?
- Can we identify the key processes (from models and expert understanding) for each of the identified strata?
- What is the temporal variability associated with those processes?
- Can we use this understanding to prioritize what and when we should monitor in those strata?
- What impact will the integrated monitoring have on existing surveys?
- How should the monitoring be coordinated and managed – who does what?
- Time line and tasks for operational implementation – what are the impediments to overcome/address?

Annex 4: Recommendations and actions

Recommendations

Recommendation	Adressed to
1. Analyse the effects of a new design on the precision of the used stock indices	WGISDAA and IBTSWG (in cooperation)
2. Analyse vessel/country effects in the fish age data	WGISDAA and IBTSWG (in cooperation)
3. Compare the macro-epibenthos catches in species composition and quantity of at least IBTS Q3 and Beam Trawl Survey catches	WGBEAM and IBTSWG (in cooperation)

Actions

Steps	Actions	Who/How?
Step 1 (existing monitoring)	Different policy driver requirements for integrated assessment of ecosystems, overlap between MSFD, Habitats, CFP, WFD, etc.	to be decided
Step 2 (ecosystem processes)	Define and agree the precise boundaries of the identified 11 North Sea strata. Describe in detail the key processes operating in each strata along with the most important parameters to monitor (see Table 3.2.1 and 3.4.1). Determine the most effective/currently preferred sampling technologies to monitor parameters either individually or in combination. (NB. applies to autonomous sampling devices or sample processing).	GIS WG? ICES Data centre? WGINOSE/Other expert groups/workshop? WGINOSE/Other expert groups/workshop?
Step 3 (evaluation)	Determine the optimal number of sampling stations to appropriately assess each parameter of importance within each strata. (data users to identify criteria for new end-users, for existing data collection analyse the effects on the precision of the index). Determine the necessary temporal frequency of sampling for each parameter or combination of parameters. An analysis of the temporal variance of the identified parameters in each of the strata to determine how sensitive each strata are to the number of stations sampled. (is this the best survey to do the activity? Already discussed in principle)	to be decided

	The analysis should also take into account vessel/country effects in the sample data. (examined for commercial species and elasmobranchs –to do: age level) To assess the impact of changes in station numbers on meeting the different policy objectives, e.g. in providing stock assessment advice under the CFP, meeting the assessment needs of descriptors 1, 3, 4 and 6. How different sampling technologies can be used to improve efficiency of monitoring. (other platforms and methodologies).	
Step 4 (redesign)	Define sampling design for each parameter, e.g. random stratification based on a substantial set of 'safe' stations.	
Step 5 (implementation)	Optimize implementation of Q3 vessel operations/surveys. Priorities for monitoring (at what point do you decide to abandon a survey due to gear failure etc.)	

Annex 5: Infauna sampling

Objectives

1) Describe the variance in species composition (species richness and abundance);
2) Describe variance in biomass as benthic secondary production;
3) Describe linkages between benthic biomass (biogeochemical + food) and demersal fish stock (predator);
4) Describe the variance in sediment grain size composition.

The suggested benthic macroinvertebrates sampling should be representative of dominating sediment habitats (e.g. accumulation or alt transport bottoms) in the area sampled.

Preferred sampling times

Traditional macroinvertebrate infauna sampling for attaining information on sediment benthos communities has been performed during Q3, because at this time the community reach maximum biomass (e.g. Petersen 1913) and are potential food for demersal fish during coming year.

For status assessments increased sampling effort has been allocated during spring to reduce variability due to natural causes (variable annual recruitment that do not survive the first winter) as well as favourable wind-, temperature and sea-ice conditions. Spring appears at very different times and sampling Q1 may describe winter-spring conditions in the different strata on a southwest-northeast gradient in the North Sea. Summer is not a preferred time since recruitment of species is variable in both time and space.

Sediment sampling for attaining information on sediment composition has no preferred season but should primarily be performed during in parallel with the macroinvertebrate infauna sampling.

Preferred sampling sites

Infauna sampling is performed on a community level where gradual change occurs but sampling effort related to spatial variability gives more information than sampling every year on the same location. Sampling should ideally follow the proposed survey stations using random (selection of possible stations) design. Additional information on temporal change could be sustained keeping a few representative stations at each stratum with long time-series data.

The suggested design will give best process understanding and tight linkage to the other data collected and more harmonized complement to macroinvertebrate infauna collection for state assessment performed in coastal and marine waters either annually, every second or third year to fulfil WFD, MSFD and other national reporting requirements. This interval may be sufficient since a majority of the fauna species that survive the first winter may have a life expectancy of more than one year.

For sediment sampling, the preferred sites are:

- parallel with macroinvertebrate infauna samples;
- representative of habitat types in the investigated area (e.g. backscatter, habitat maps, along VMS information);

- starting at one representative (e.g. dominant habitat/community) sample per haul and iteratively alter the number per strata to variance components calculated on collected material.

Number of stations needed for assessments

The JMP NS/CS project has estimated the number of stations needed in each stratum to perform a confident assessment of benthic habitat condition by benthic indicator currently used in WFD and MSFD national assessments. So called multimetric indices have been suggested as Common indicator (MMI) within OSPAR for assessing diversity in soft-bottom macroinvertebrate communities sampled using standard methods (ISO 16665). These can all be calculated using a species-abundance dataset.

Monitoring programmes ideally fit within the legal assessment cycles, i.e. the MSFD cycle of 6 years.

> In the EU JMP NS/CS project it was found that 778 benthic sampling stations (ranging from 7 to 349 per stratum, depending on the variability in each stratum and the statistical requirements of the assessment) are needed for one assessment of species richness, abundance and the AMBI benthos index, which is significantly less than the current total effort for those metrics. This sampling effort can be distributed over a period of 3 years (Van Hoey *et al.*, in prep), which would enable two assessments in each MSFD cycle.

Important data to evaluate results

- Metrological data, air temperature, windspeed, precipitation (Kattegat and Skagerrak);
- Hydrographical data, water temperature, salinity and bottom-water oxygen;
- Water column biology (pelagic), e.g. plankton biomass, chlorophyll *a*, primary production and sedimentation;
- Data on demersal fish – variation in community composition and dominating size classes;
- Data on pressures (e.g. hazardous substances, fishing activities) in the area;
- Backscatter information from surveys;
- Habitat maps;
- VMS data whole year and Q3.