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Report of the Workshop on Evaluation of current ecosystem surveys (WKECES)

20–22 November 2012

Bergen, Norway

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Contents

Executive summary

The Workshop on Evaluation of current ecosystem surveys (WKECES) met in Bergen, Norway, chaired by Sven Kupschus with the participation of 19 scientists representing 7 countries. The aim of the workshop was to evaluate four surveys with distinct ecosystem characteristics and to synthesize the results of this evaluation into advice to WGISUR as to the important considerations when developing 'ideal ecosystem survey' for the implementation of the ecosystem approach to management.

The approach taken was to evaluate the four candidate surveys separately through a presentation and plenary discussion performing a SWOT (strengths, weaknesses, opportunities and threats) analysis (Section 4 and Appendix 1). The common themes across all surveys where then picked up in plenary discussions and synthesized into the conclusions from the workshop.

Two top level themes emerged as the causes of the strengths and weaknesses for all the surveys: a) setting and prioritizing objectives (Section 6). Plenary discussions linked the decisions in survey approach to the specific strengths and weaknesses and b) survey design and the need to be able to elucidate process by explicitly linking dynamics in different ecosystem components (Section 5).

It became clear that some of the strengths were mutually exclusive, either operationally or conceptually, and therefore an 'ideal ecosystem survey' on a single vessel, is unlikely to exist. An ecosystem monitoring program that has at the heart of it one or more ecosystem surveys is required and these must go beyond strict status observations and link different ecosystem components with each other or the physical environment. The prioritization of these surveys should be based on three factors:

- the characteristics of the ecosystem particularly with respect to the spatial and temporal scales of variability.
- the available resources in ships time, but also expertise and financial considerations. International pooling of resources will aid to increase efficiency and improve regional ecosystem assessments across national boundaries.
- the management and legal requirements and prioritizations for reporting. This is not a scientific criterion, but an ability to address the former will almost certainly have an impact on the availability of resources.

Policy-makers and funding bodies need to be made more aware of the benefits of integrated monitoring vs. the current discipline-specific monitoring programs. The former provide advice based on an understanding of ecosystem process identifying how to act rather than merely identifying critical situations. Therefore both the surveys and the advice provide significant advances in efficiency.

1 Opening of the meeting

1.1 Terms of reference

The Workshop on Evaluating current ecosystem surveys (WKECES), chaired by Sven Kupschus, UK, will meet in Bergen, Norway, 20–22 November 2012 to address the following terms of reference:

a) Evaluate a range of current fishery and ecosystem surveys in relation to the flow diagram as prepared by WGISUR 2012;

b) Provide a SWOT analysis (Strengths, Weaknesses/Limitations, Opportunities, and Threats) for each survey;

c) Provide recommendations for improvement of the survey;

d) Provide advice on prioritization procedures for the different objectives implicit in an integrated ecosystem survey.

WKECES will report by 15 December 2012 for the attention of WGISUR, and by 15 January 2013 (via SSGESST) for the attention of SCICOM and ACOM.

1.2 Adoption of the agenda

No formal agenda was adopted for this meeting, as it was expected that the process would be rather fluid given the fact that the outcomes of the SWOT analyses of the individual surveys were unpredictable, however the general plan outlined below was submitted to all participants prior to the meeting.

"The plan is to evaluate the surveys sequentially (ToR a and b) in subgroups following a 1 hour presentation by the survey leader. The following plenary session is then designed to distil the conclusions from the subgroups and provide feedback to the survey design team (ToR c). Following the presentations over the first two days the final day will be spent putting together the more general conclusions about what we have learned from the experience with respect to addressing ecosystem surveys and ways to proceed in future when designing and modifying surveys (ToR d). An important step here will be to highlight the SWOT analysis in the context of the ecosystem and if and how this could relate to other ecosystems. I am hoping during this time that we will also be doing some writing as Dave has set a very short deadline for reporting because the information is vital for WGISUR to proceed in January.

Following some preliminary consultation we will evaluate starting at 9:00 on Tuesday.

The UK Western Channel Beam Trawl Survey, Morning of the 20th

The Joint Barents Sea ecosystem survey; Afternoon of the 20th

The German Small-scale Bottom Trawl Survey, Morning of the 21st

The French Pelagic Ecosystem survey (including other Atlantic pelagic surveys) – PELGAS, Afternoon of the 21st

In addition IMR is organising a seminar on during lunch time on the 21st with respect to their ecosystem survey in the Barents Sea. This will likely cover some of the aspect of the evaluation but should also give a wider picture so this may be a good opportunity to gain some extra insights."

2 Introduction

The call for the workshop came from the realization that there were different approaches to ecosystem monitoring, but it was unclear as to what the unconditional ideal solution would be. Without this it was difficult to evaluate how to most effectively and efficiently progress towards that ideal. The paragraph below from WGISUR 2010 elaborates on this thinking.

The ideal fishery and ecosystem survey

What are the requirements of the ideal fishery ecosystem survey? One of the issues identified in the TGISUR meeting in 2009 (ICES, 2010) was the redesign of surveys for an ecosystem approach. It is proposed that WGISUR should produce guidelines and/or a template for the best practice combined ecosystem and fishery survey. This would be based on the feedback from ICES ecosystems EG responses to the data tasks table, and the feedback from the survey EGs on the options within their surveys (see Section 4.2 above). Depending on feedback, the approach could involve potential redesign of an existing survey to incorporate pertinent ecosystem factors that are feasible to collect, for example based on the IBTS or other existing surveys. Alternatively, the approach could be to develop a complete, designed for purpose, ecosystem and fishery survey.

In developing this workshop it became clear that the 'ideal fishery ecosystem survey' depended very much on the objectives and the advent of national government ecosystem reporting requirements. For the EU countries this is largely formalized by the Marine Strategy Framework Directive (MSFD), but other countries also have ecosystem management high on the environmental agenda. These factors change the landscape under which one might asses the ideal survey. The recognition that objectives are fluid and therefore there will never be a single ideal fisheries ecosystem survey lead to the approach of evaluating current ecosystem surveys to examine how they performed against the design criteria developed by WGISUR (flow diagram) and to see what information towards the EAFM they delivered. The aim was then to summarize the strengths and weaknesses of the individual surveys into generalities as to what one should be striving for in an ecosystem survey.

3 Strength, Weakness, Opportunities and Threats analysis of current ecosystem surveys

This section consists of a summary for each survey, essentially summarizing the presentations given at the workshop, followed by a table of strength, weakness, opportunity and threats and a summary of the points discussed under the same general headings for each survey as discussed in plenary. The full list of comments by participants is provided in Appendix 1 for each survey.

3.1 The Joint NOR-RUS Barents Sea ecosystem survey (BESS)

Summary description

The BESS was initially started as a combination of several surveys in summer/autumn. These surveys included: the 0-group pelagic trawl survey (including hydrography) conducted since 1965, the joint acoustic capelin survey conducted since 1975, a demersal trawl survey for juvenile Greenland halibut and redfish covering the areas north and east of Svalbard, as well as two additional Norwegian demersal trawl surveys. Since 2005 also the Norwegian shrimp survey (demersal trawl survey) was included into the multipurpose survey as we refer to as the BESS. These surveys were carried in about the same time. These surveys are fundamental for single-stock fisheries assessments (e.g. capelin, shrimp), supporting single-stock fisheries assessments (cod, haddock and other demersal fish), providing long time-series of 0-group fish and hydrographic conditions, and monitoring interactions by trophic studies of pelagic (capelin and polar cod) and demersal (cod) fish. The BESS was initiated in 2003, but an agreement between IMR and PINRO about the principal methods for execution of the survey was not reached before 2004. With respect to data analyses and time-series, the survey data are therefore viewed as "official" from 2004.

Exploration

During the nine years of BESS, we have obtained better understanding of the ecosystem components and processes based on output of the survey. In the later years this, knowledge has been documented in more than 70 scientific papers and 14 survey reports, which together with other sources of information have been assembled in the books: "Ecosystem Barents Sea" (2009, ISBN 978-8251924610) and "The Barents Sea ecosystem, resources, management. Half a century of Russian-Norwegian cooperation" (2011, ISBN 978-8251925457) This is the basis for the definition and description of e.g. physical, chemical, and biological components and important processes in the Barents Sea ecosystem, used as a reference base for the BESS today.

Aim and objectives

The aim of the ecosystem survey is to monitor the state of the Barents Sea Ecosystem to support scientific research and management advice.

The objectives were largely adopted from earlier surveys, and several objectives with focus on plankton, benthos, marine mammals and seabirds, pollution and biodiversity were gradually integrated in the BESS, however the prioritization of objectives for the monitoring of the whole ecosystem were not formally discussed before 2011, and prioritization of resources towards prioritization of objectives still not been developed yet.

Resources

BESS have been organized and financed by different ways: as one project which was leaded of one person (coordinator) from each country or team, as several projects, which were responsible for finance own investigation (fish, plankton etc.) and coordinator, who combined and design survey. Our experience is that team organization is more appropriate to coordinate due to planning are time consuming, interactions with several scientific disciplines challenging to balance, and therefore underestimation of this work may negatively influence conducting of survey, collecting data and inefficient survey effort.

All technicians who participate in BEES belonging to IMR and PINRO, except marine mammals and seabirds observers from Norway, which make it easier to manage the survey. Additionally, all participants are schooled to carry out multi-tasks sampling.

Ship time (days at sea) is crucial to cover a huge area, therefore will a decline in ship time coarse an insufficient temporal coverage may negatively influenced the geographical coverage, station frequency, number of equipment per station, processing of the samples and consequently the amount of data collected and quality of the data.

Survey design

The survey design of BEES consists of a uniform sampling intensity in the general survey area as well as a random bottom stratified sampling around the Spitsbergen archipelago (http://www.imr.no/filarkiv/2005/12/ecosurv_rep_2005.pdf/nb-no). A regular sampling coverage of the Barents Sea is suitable for multi-task monitoring and covers a large spatial area. This makes, in combination with the adapted sampling for special purposes (e.g. oceanographic sections and mature capelin core area), the survey design suitable to monitoring ecosystem.

Methods

To cover the most aspects of the ecosystem (from physical and chemical oceanography, pollution, phytoplankton and zooplankton, fish (both young and adult stages), sea mammals, benthic invertebrates and birds) a range of methods and gears are applied, from water sampling using a CTD equipped with a water bottle rosette sampler, to plankton nets, pelagic and demersal trawls, grabs and sledges, echosounders and direct visual observations (Table 1, Michalsen *et al.*, 2011).

Research priorities

The research priorities must closely follow the priorities of the objectives, and the objectives should be better described and prioritized than they are today. Additionally, an ecosystem team should improve the research priorities for the next 3 years with focus on trophic interaction among species at all levels.

Cooperation

BESS is a joint effort between Norway and Russia, based on collaboration between the two countries since beginning of 19th centuries. The development of the BESS was possible due to international agreements, an attempt to improve the efficiency at the survey, and by enhancing the ecological focus and scientific merit of joint surveys. The well-coordinated effort in planning, implementation and reporting of a survey of this size is unique in an international context.

The survey is described in detail in Michalsen *et al.* (2012), the sampling manual and survey report are available on BESS website:

http://www.imr.no/tokt/okosystemtokt_i_barentshavet/survey_report/nb-no

Strengths	Weaknesses
1. Well-coordinated effort in planning, implementation and reporting based on highly functional international collaboration between Norway and Russia. 2. Comprehensive spatial coverage and adequate resolution enable capturing of large-scale changes in spatial distribution due to climate variation and other factors. 3. Optimal seasonal timing for covering maximum distribution of key components, occurrence of both immigrating and local species, and period of least ice coverage. 4. The results/output covers important assessment tasks and several ecosystem components and processes, e.g. single-species stock assessments, and process understanding (stomach sampling of cod) 5. The multidisciplinary focus of the survey increases the scientific knowledge of the ecosystem as a whole, and the competence scope of both those involved and users. 6. High level of dissemination of results in the form of reports, stock assessments, management plan, scientific publications. Results also widely used in internal and external projects.	1. Poor definition and prioritization of aims and objectives result in difficulties in effort allocation between different tasks. 2. Lack of long-term perspective in planning gives few opportunities to consider complementary sampling at surveys in other seasons, and infrequent sampling of certain components (e.g. every 3rd year.) 3. Retrieval of data for integrated analyses is cumbersome due to lack of joint RU-NO databases for certain components. Further, databases on different components are not coupled (e.g. temperature/plankton/fish). 4. Reduction of resources (time and money) parallel with increased demand for covering more ecosystem components, processes, and area, results in mismatch between objectives and resources. 5. Survey design and sampling procedures were adopted from the earlier surveys combined into this survey, and therefore statistical issues related to this are insufficiently addressed. 6. Due to the seasonal timing in autumn the survey misses some important ecosystem processes taking place in other seasons.
Opportunities	**Threats**
1. The survey is a 'data rich' scientific platform with the potential to address current/future ecosystem questions and truly temporal patterns in relation to e.g. climatic change 2. High resource allocation (e.g. ship time, expertise and funding) gives opportunity for flexibility 3. Development of new data systems facilitates integrated analyses 4. Solid basis for developing integrated ecosystem assessment 5. Can push development and improvement of methodology and technology due to efficiency requirements of simultaneous monitoring. 6. Open possibilities for further funding	1. Decreased ship time 2. Decreased funding for survey and subsequent analyses 3. International collaboration stops if Russia or Norway decides to no longer participate. 4. Discontinuity of scientific personnel involved (e.g. annual change of a part of the scientific personnel involved from IMR) 5. Restriction by the Russian Defence Ministry to work in the some parts of the REZ

SUMMARY OF PLENARY DISCUSSION FOR YOUR SURVEY BY HEADING

1. Survey design and timing

comprehensive spatial coverage and adequate resolution uniformly spread sampling grid ensures good coverage of the total area. The BESS is a comprehensive survey that collects information on a wide range of ecosystem components. The survey design for station allocation is based on stratified systematic sampling, with uniform distribution of stations over the whole survey area. This is an effective design for a survey with multiple objectives, and is ideal for mapping. Due archive suitable coverage for some objectives the stratified random design with stratum defined by depth zones (around Svalbard), the uniformly spaced grid points within capelin area were used. The combination of systematic sampling, with uniform distribution of stations over the whole survey area and adoptive design for special porpoises is suitable design due to multiple objectives.

seasonal timing optimized in relation to primary goals (0-group capelin) For the BESS early autumn period was chosen first of all because of the 0-group survey and the capelin survey, which both are dependent of this period (the capelin stock has minimal migration during this period and 0-group is large enough to be caught effectively in trawls). However, one of the strengths with carrying out this survey during this period, is that most of or the whole Barents Sea is ice-free, and hence the total distribution area of all Barents Sea stocks can be covered. Also, near the end of the feeding period, it is possible to assess the outcome of the annual production. For groundfish, shrimp and others, this period is not necessarily the most ideal, taking fish behaviour into consideration.

Survey results/output:

- *surveys results covers important ecosystem components and processes*
- *delivery of important data for single-species stock assessments besides stock assessments, results also widely used for projects, Barents Sea management plan, publications*
- *time-series data*
- *obtaining data for of many ecosystem components and process*
- *establishing a comprehensive database (or Barents Sea monitoring polygons meta-database) for all element of the survey*
- *Systematic sampling, lack justified variance estimator for abundance estimator*
- *High level of dissemination of results:*
- *Published data*

Website for the survey (www.imr.no/tokt/okosystemtokt_i_barentshavet), which also includes Sampling Manual and Survey Report.

2. Prioritization:

objectives largely based on the objectives of previous targeted fishery surveys, and priority remains here and integrated objectives for the whole ecosystem were not formally developed Reduction of effort parallel with increased demands results in mismatch between objectives and resources

3. Collaboration:

Highly functional international collaboration between Norway and Russia. Collaboration provides a 'true' sea wide assessment. Not restricted to regional waters as many surveys are

Data availability, NO – RU agreement on mutual use of the data

3.2 The French and Spanish Pelagic Ecosystem Survey – PELGAS / PELACUS

Summary description

The first objective of PELGAS surveys (PELagic GAScogne) was at the origin, the assessment of small pelagic fishing resources, mainly anchovy (since 1989). Anchovy is a short live species, 70% of the population is age 1. Therefore, the biomass level is closely dependant on the recruitment level and a yearly assessment is essential.

The yearly assessment is performed through a Bayesian model based on two biomass index: an acoustic index and a DEPM index. PELGAS surveys are carried out in spring each year since 2000, but previous acoustic surveys occurred since 1989 (with some gaps along the series) following different transect strategies and with less acoustic frequencies.

As the anchovy biomass fluctuations are mainly based on recruitment, PELGAS surveys aimed to collect as much parameters as possible which could explain in future the recruitment determinism. The new "Thalassa" vessel arriving in 1996 gave a lot of possibilities to collect data in good conditions. It was therefore a good opportunity to add new tasks to assessment purposes and create the present ecosystemic PELGAS surveys series which is able to day to bring appropriate data for MSFD requirements.

In this frame, the pelagic compartments are characterized at each trophic level (see presentation on the SharePoint site). To assess an optimum horizontal and vertical description of the area, two types of actions are combined:

During daylight : Continuous acquisition by storing acoustic data from five different frequencies, pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler), and visual counting and identification of cetaceans and birds (from board) in order to characterize the top predators of the pelagic ecosystem.

During night: discrete sampling at stations (by trawls, plankton nets, CTD) for a vertical environment characterization.

As the first objective is to assess pelagic fish abundance, acoustics constraints were maintained to be the priority in terms of strategy, during the first 30 days constituting the total area coverage. During this period, as many other observations as possible are collected and all the available ship time is used to collect environmental parameters.

One additional week is used at the end of the survey for special operations, additional sampling, process studies and method optimization.

PELGAS surveys are funding by DCF at a level of 50% for the 30 days corresponding to the total coverage of assessment area.

PELGAS surveys are coordinated inside an ICES group (WGACEGG), where all pelagic surveys are represented: spring and autumn, acoustic and egg surveys, from Gibraltar to Ireland.

In WGACEGG coordination context, the PELACUS survey (IEO, Spain) is carried out each year just before PELGAS and covers the Spanish platform from northern Portuguese waters to south of France. The time-series of PELACUS surveys starts in 1984; initially developed to estimate the biomass of (*Sardina pilchardus*). Nowadays; the objective is the study of all pelagic ecosystem components and connexions between them (stomach contents; stable isotopes, etc.). The protocols of both surveys (PELACUS and PELGAS) are globally identical except an 8 nautical miles inter-transect and no commercial vessels during the whole survey.

Reference (Full reference list of publications based on the PELGAS in Appendix 3)

Strengths	Weaknesses
Objectives well defined, and including monitoring of many aspects of the pelagic ecosystem (biotic and abiotic), and are clearly prioritized (in favour of acoustics for assessment) results used in assessment (DCF funded) Long-time-series available, following the same strategy (based on previous geostatistic analysis) Internationally coordinated (WGACEGG), common database (under construction) Assessment of birds, mammals, turtles, sharks, floating litter and plankton consort survey with commercial vessels additional time at the end of the systematic total coverage, in order to clarify particular methological problems or ecosystem components or processes	DCF funds partial (no funding for the extra week, no continuity in funding for commercial vessels) only focused on pelagic ecosystem and mainly on one species (anchovy) / species group (pelagics) Target strength uncertainty inshore (shallow water) communities/ecosystem(s) not sampled wide range of databases/Excel files/text files for different types of data possible bias with sampling south to north
Opportunities	**Threats**
possible expansion of communities it can assess future combination with autumn bottom trawl survey (EVHOE) future combination with Spanish autumn surveys (JUVENA) opportunistic sampling aims combination of all the data, at least initially through overlay of the datasets on maps: Top predators, pelagic fish, zooplankton, hydrographic data, water chemistry through WGACEGG. The assessment of microplastics from plankton tows	Impossible if national funding decrease, particularly for "extra time" addressed to specific questions on ecosystem function or methodology (no EU funding for this extra time). Possible loss of commercial vessel collaboration (in the absence of future funding): reduced accuracy of identification of echoes

SUMMARY OF PLENARY DISCUSSION FOR YOUR SURVEY BY HEADING

Survey design

- *Spatial and temporal coverage.* Spatial coverage is comprehensive, covering the entire shelf and a wide area from with PELGAS, PELACUS and PELAGO surveys. The only weakness is the lack of coverage of the northern area (Celtic Sea).
- *Eco-components. The pelagic compartment is well sampled however the ecosystem extends beyond the pelagic system.* The survey was designed to address questions related to the abundance of pelagic fish resources. It was deemed that the large spatial scale over which these resources migrated on an annual basis would require an extensive survey and a rapid completion in order to avoid migration issues particularly for the transect work. These operational conditions in conjunction with resource limitation led to the decision to constrain the work to the pelagic compartment, but to do in depth ecosystem work in that area, rather than overstretching available resources and time and produce poor quality results on the entire ecosystem.
- *Systematic designs can introduce bias, you should consider a random transect design.* The strength of the design is very much that it is representative of the ecosystem, and the higher degree of precision that one gets from a systematic design. The transect distance is specifically set to match the known scale of spatial variability of the pelagic system, though it may be in appropriate for demersal components. It would be appropriate / interesting to revisit the spatial analysis to examine if and where the approach could be improved. For example intensify in special locations (not for all area, nor all years). The extra week is an opportunity to make narrower transects and to develop new methodologies.
- *Is the process oriented work conducted on the survey sufficient?* It is true that a large proportion of the survey effort (30 days) is dedicated to status based observations which are delivered consistently through the time-series. However the status based observations are collected in a way that they can be used to infer process for several ecosystem interactions. In addition, one week is available in the survey to conduct specific process work either to address specific ecosystem questions (one off's) or to examine new survey methodologies and improve future survey efficiency and applicability.

Prioritization

- *Fish priority.* Funding comes from the DCF with the objective of fish management, not ecosystem. This is not strictly true, some environmental information is encouraged under the DCF, but the process based work (the pelagic ecosystem work) emanates from the interest of the scientific staff and the appreciation that the ecosystem has an important role to play in the productivity of fisheries resources and that it is hence vital for appropriate fisheries management.
- *Ecosystem management relevance is unclear.* The survey has the potential to be highly relevant to ecosystem assessments, however it is not certain if and how the data have been used in the current MSFD assessment or how the data streams will be considered in future ecosystem assessments. Funding and hence objectives for the ecosystem components beyond fish

are not specifically tied to objectives so that this information may not necessarily be available in future unless the survey is more formally incorporated into the assessment process. The survey is formally used in the assessment of pelagic fish stocks where its coordinated design and methodology standardization with other surveys (PELGAS, PELACUS, PELAGO) greatly aids its utility and relevance.

- *Pressure weighting.* The design is a regular systematic design and is therefore not weighted towards any specific pressures, although the aim of maintaining the specific transects each year is based on considerations by oceanographers to have information near specific freshwater inflows, where the nutrient and contaminants information could be considered as part of the human pressure question.
- *Collaboration.* Collaboration with other experts and Institutions in France (universities, etc.), international collaboration for the survey design and data analysis (Spain, Portugal, UK,...)
- *Utilizing fishermen's knowledge/skills has been an effective method of increasing data accuracy.* Using fishermen who know the area has helped significantly in many ways, not just their expertise in providing accurate echo-return interpretation. The survey uses the fishing vessels strategically to collect fish samples, often freeing up the RV to continue acoustic transects or to conduct other ecosystem work. Working with fishermen also provides a platform for the transfer of information. When fishermen are part of the process, management if more commonly understood and accepted. Unfortunately funding for this work has come to an end last year and efforts to secure a more formal long-term agreement to continue with this work have as yet been unsuccessful.

<u>Other</u>

- One of the strengths of the survey is the continuous development of new methodologies for improving the surveys design (PELGAS and PELACUS), coordinated through the WGACEGG.

3.3 The German Small-scale Bottom Trawl Survey (GSBTS)

Summary description

The Germans Small-scale Bottom Trawl Survey (GSBTS) is an otter board trawl survey that has been started in 1987, after a pilot study in 1986 (see extended description of the survey in Ehrich *et al.*, 2007). Its <u>objective</u>s evolved to some degree over the 25-year time span since, starting from its original motivation to cross-validate findings of the IBTS. In the meantime, additional objectives have become important, particularly (1) Obtaining long-term data on various ecosystem components, (2) Providing a platform for additional process studies – beyond those directly related to the IBTS, and (3) Evaluating human influence on habitats and demersal communities.

The <u>survey design</u> is random stratified in the sense that survey areas, "Boxes" of 10 by 10 nm each, are predefined, and the actual fishing hauls are randomly placed in position and tow direction. The position of the initial set of boxes was selected in areas of high known abundances of gadoids (in accordance with the original objective); lateron boxes were added to reflect various characteristic habitats and water masses within the North Sea as a whole. The survey is run annually during the third quarter and was originally conducted by one vessel ("Walther Herwig"), until the expansion to meanwhile 12 boxes required the involvement of a second vessel ("Solea"), with the advantage that all boxes can be sampled within a month, but the disadvantage that the two vessels have to use slightly different gear ("Solea" due to technical constraints cannot use the GOV, but also uses an otter board trawl with identical codend mesh sizes). The sampling methodology for the fisheries component of the GSBTS is identical with the IBTS; the "Walther Herwig" uses the GOV net in the same setup.

The survey is multidisciplinary, involving experts from several institute to cover regularly besides fisheries ecology and hydrography also benthic ecology and seabird observations (on the larger ship) or plankton sampling (on the smaller ship). Further additional sampling programs depend on the requirements for process studies.

The original survey goal was pursued through obtaining local abundance indices for gadoids and comparing them to IBTS-indices, furthermore through testing of survey methods, and through the evaluation of vessel and gear effects. Since then, the principle understanding of ecosystem processes at small scales (within one or a few nautical miles) has remained a key objective of the GSBTS, applying a comparison of variability of fish abundance and distribution at different spatial scales and feeding into geo-statistical analyses and information for fish distribution models.

The now available long-term datasets of multiple simultaneously observed ecosystem components at the survey sites allow for evaluation of climate change effects. They are also prerequisite for parameterization and validation of ecosystem models. Process studies have been conducted both, in a planned manner or opportunity-dependent – examples of the latter being the quantification of predation in small-scale predator hot spots, or the evaluation of gale effects on demersal communities. The research projects conduced within the GSBTS have been published in many peer-reviewed articles and ICES working documents (Annex 2).

Evaluation of human impact will become important in some areas of the GSBTS, which are being increasingly affected by infrastructures of the energy sector or may in future be influences by neighbouring MPAs or windfarms. The evaluation of fishing effects is planned.

Comment: For further details of the survey objectives, methodology and results, please refer to the presentation held at WKECES in Nov. 2012 (on the SharePoint site), and to Ehrich et al. (2007).

Reference (Full reference list of publications based on the GSBTS in Appendix 2)

Strengths	Weaknesses
DESIGN: Spatial scale and high-resolution sampling more appropriate than larger scales (IBTS) to investigate species interactions.	VESSELS: Half of the Boxes are sampled with another ship (due to limitations in ship time, but with the advantage of synchronous sampling). While the individual Boxes are always sampled with the same ship and direct comparability for the time-series of the same ship is given, comparability of quantitative data between both ships is limited.
TIME-SERIES: Long time span covered: Survey begun in 1987 and has been continued since.	VESSSELS: Both vessels involved have different options/constraints for sampling additional ecosystem parameters.
DESIGN: Design suitable for process studies, potentially complementary to IBTS (same gear and method). Useful to deliver ecosystem indicators.	COVERAGE: Not all water masses or benthic habitat types in the North Sea are sampled.
ECOSYSTEM: Various ecosystem components sampled (see details above/ in presentation and review paper)	COVERAGE: Individual Box areas are relatively small. Therefore, the survey area covered is limited
DESIGN : Hauls within a Box are distributed over the sampling days both in time and space	OBJECTS: Objectives developed over time
OUTPUT: Large number of peer-reviewed papers on survey results, various topics	TIME-SERIES: Length of time-series covered differs between boxes as original survey started 25 years ago with only 4 boxes.

Opportunities	Threats
ADDITIONAL PARAMETERS: Opportunities for inclusion of additional measurements (resources prerequisite). Examples: Plankton sampling, hydroacoustics, underwater video observations for habitat mapping, link to remote sensing data. INTERNATIONAL PARTICIPATION: Opportunity for other nations to join in, e.g. by adding a new "Box" in an area of particular interest in their EEZ, for example near a designated MPA. Potential for international coordination. INTEGRATION: Combination with other long-term datasets for the North Sea. INTEGRATION: Evaluation of effects of human pressures, e.g. fishing intensity through combination with VMS analyses. DESIGN: The survey design could benefit from an addition of 1 or 2 Boxes, which are each year randomly placed within the greater survey area. This would add to the coverage of different regions/habitats in the North Sea.	RESOURCES: A demanding programme in terms of resources AREA RESTRICTIONS: In some "Boxes" (survey areas); human activities have had a significant influence, particularly through installation of infrastructures (e.g. oil rigs, pipelines) that diminish the accessible space within the Box. Additional installations would further impair the choice of fishing positions. LINK TO ASSESSMENT: Currently, no direct link to stock assessment. This could be viewed as a disadvantage when funding is considered.

SUMMARY OF PLENARY DISCUSSION FOR YOUR SURVEY BY HEADING

Survey design

Spatial and temporal coverage: *Long-term dataset, multidisciplinary: Start of survey in 1987, initially covering four sampling areas (Boxes), meanwhile twelve. Time-series lengths vary between Boxes.* The survey is conducted annually during the third quarter to match the time window for the Q3 IBTS. Meanwhile, the time-series exceeds 25 years for the Boxes of the original survey. The number of Boxes samples has been increased over a number of years to cover additional regions of the North Sea. Although sampled through a national program, the 12 Boxes are not restricted to the German EEZ but distributed over the whole of the North Sea.

Eco-components: *Additional ecosystem components are sampled besides fish (benthos, plankton, seabird observations, and litter). Provides a direct link to the benthic communities. Different additional investigations/ process studies in different years in different Boxes (e.g. fish stomach, infauna). Survey areas cover different parts of the North Sea ecosystem(s).* Different trophic levels are regularly investigated simultaneously, including benthos (infauna and epifauna). The survey thereby offers the possibility to examine small-scale ecosystem processes, for example trophic interactions between predatory fish and forage fish, or predation of fish on benthic organisms. Seabird observations performed for the Seabirds at Sea program utilize the longer steaming times between Boxes to count the birds at the open sea. The sampling days within a Box with only short steaming distances are used to monitor ship-following birds with accompanying experiments on discard feeding behaviour. Due to the different constraints of the two ships involved in the survey (particularly size of the scientific crew), different additional ecosystem components are sampled with the two sets of Boxes, e.g. seabird observations are only possible to be conducted on the larger ship. Additional process studies are being planned for individual years, such as analyses of stomach contents of particular fish species or sampling of infauna in additional regions. These time-consuming extra tasks cannot be conducted every year and do not cover the full time-series.

Plankton sampling could be conducted through coupling with CTD casts (LOPC or plankton nets). No acoustic surveys (production of habitat map) in relation to the benthic communities and fish communities. Options for incorporation of acoustic habitat mapping techniques alongside observations of fish distribution patterns within the survey areas are being evaluated as a way to gain further insights to habitat utilization. Underwater video would be another option to visualize the habitat, and to study how fish interact with their habitat.

Design and representation of the ecosystem: *Within the Boxes, random station selection and random tow direction. Randomized design (but with some subjective selection of hauls to ensure coverage of the area of the Box).* Hauls within a Box are for the entire three-day sampling period in a first step selected at random. In a second step, the hauls are allocated subjectively to the three days in a way the hauls cover more or less the full Box area during each day. The reasoning behind this selection of sampling order is that in case of a disturbance during the three-day sampling period, the partly different habitats within the Box should still be covered. Such a disturbance could occur e.g. through a technical failure of the ship leading to reduced station numbers, or through a storm event affecting the fishing hauls during or after the event.

Replicates within "primary sampling unit" (Box). Typically, 21 hauls are conducted within an area of 10 x 10 nautical miles.

The place of "Boxes" could not reflect all processes/habitats in the ecosystem. The design is based on fixed Boxes (that should represent the range of habitat types) that are far away from each other makes it difficult to pick up ecosystem changes/processes in between these Boxes. The spatially highly resolved sampling within the Boxes comes at the prices of a limited area which the survey can cover. Consequently, the GSBTS does not cover the North Sea in its entirety. For example, there are no Boxes in some areas which can be expected to be significantly different in their environmental conditions, like locations within the Skagerrak water or the Scottish or English Coastal water (*sensu* Laevastu, 1963). The question arises of how far it is possible to extrapolate results from within the Boxes to a larger scale. For some assessed species, a statistical evaluation of the effect of up-scaling abundance indices has been pursued, revealing species-specific differences, and in some instances surprising similarities (S. Adlerstein and S. Ehrich, in: Final Report of the EC Study 98/029). The large number of replicate hauls within a small area supports obtaining a rather representative picture of the (local/regional) fish assemblages present, whereas in the IBTS a large number of replicates for a more representative picture is obtained (only) on a large spatial scale.

Gear: Standard gear, same GOV as in the IBTS. Monitoring of gear behaviour. Standard sampling techniques (grabs and benthic trawls). Catchability is species dependent; effects of shorter (than 30 min) tow durations could be examined. The larger of the two ships involved in the survey, covering six of the 12 Boxes, is the same vessel as involved in the IBTS Q3 survey and uses the same methodology: an GOV otter board trawl with monitoring if the net geometry. The techniques applied for the sampling of benthic epifauna (2-m beam trawl) and infauna (van Veen grab) are the standard techniques as they have been agreed upon e.g. within the ICES Benthos Ecology Working Group. Due to its lesser size, the second vessel involved in the survey has to use a smaller otter board trawl, but equipped with the same codend mesh size. Effects of tow duration have been evaluated with the GSBTS in a study looking at the effects of shortening the former IBTS haul duration from 60 min to 30 min (Ehrich and Stransky, 2001 = The influence of towing time, catch size and catch treatment on species diversity estimates from groundfish surveys. Arch. Fish. Mar. Res. 49 (1): 37–44). Moving toward even shorter haul durations would affect the likelihood of recording the presence of rare species. Furthermore, the comparability to the IBTS is intended with the design. Therefore, a further change of the tow duration is at present not being considered

Small Box area, many replicates: Could the many hauls themselves impact the local fish abundance? This aspect has been raised during the plenary discussion, it has not yet been quantitatively analysed in detail. However, the area sampled annually with the GOV (calculated as typical net width x haul distance x 21 hauls) is less than 0.5% of the Box area and hence a significant impact on local fish abundance does not appear very likely.

Design: The ecosystem is defined as 'North Sea', not (a lot) ecological information seems to have been used to define strata, same for anthropogenic pressures (especially fishing pressure). The positions of the first few Boxes have been selected based on the original objective to evaluate abundance indices for gadoids obtained through the IBTS. Therefore, they were selected in view of to-be-expected occurrences of gadoids. The positions of all additional Boxes have been selected to reflect what were expected to be important bio-geographical regions of the North Sea habitats and cover various depth strata and hydrographically different areas of the North Sea. Significant differences between the fish assemblages in the Boxes in these different water masses have been shown since (Ehrich *at al.*, 2009 = Ehrich, S., Stelzenmüller, V., and Adlerstein, S. (2009). Linking spatial pattern of bottom fish assemblages with water masses in the North Sea. Fisheries Oceanography 18:1, 36–50). As in the IBTS, the decision for the GOV otter board trawl as a standard gear restricts the survey to habitats on which this gear can fish, and therefore is under-representative for rocky habitats.

Some Boxes have been impacted more than others over the time-series but this cannot be extrapolated to the North Sea scale. While the existing Box areas were originally affected little by interference with other human activities, the expanding by e.g. installation of oil and gas platforms does by now significantly affect the options for fishing in certain Boxes. At the same time, the survey design offers possibilities to investigate the impact of human uses of the sea - including fishing pressure. Options and constraints for such investigations arising from intensified and reallocated human activities – including wind farm construction and MPAs – should be evaluated, and should be considered in the case that additional Boxes are included into the survey.

Random towing direction without recording current speeds and directions clearly has advantages, but also the major disadvantage that these parameters cannot be used as a factor in any analysis. Introduction of operational risk: environmental factors impact on ability to fish when fishing in random direction: if tows are in a poor direction against prevailing conditions, they may not be able to fish properly or catch rates may be reduced. This issue has been discussed intensely during plenary. However, previous investigations have led to the conclusion that it is overall advantageous to leave both factors - tow positions **and** tow directions - to random selection (Sarah Adlerstein pers. comm.; S. Adlerstein and S. Ehrich, in: Final Report of the EC Study 98/029, "Survey-Based Abundance Indices that account for fine spatial scale information for North Sea stocks (FINE)").

Management relevance: *The relevance to stock assessment, if limited will funding continue?* The survey results per se do not enter stock assessment procedures. However, the GSBTS has been used to validate and quality-check abundance indices obtained through the IBTS (see above). In this, it has the advantage of needing limited resources in terms of ship time and steaming distances to pursue its investigations in one particular (Box) region. The objective of conducting evaluations still exists, and the survey offers complementary information to the IBTS and many options for ecosystem monitoring, both in terms of ecosystem status (e.g. biodiversity indices) and processes (e.g. trophic interactions). The GSBTS has also been applied for the evaluation of long-term regional changes related to climate change.

Pressure weighting. The survey has not originally been intended to monitor human impact directly. However, in the meantime some Boxes have been subject to installations of infrastructures such as oil rigs, pipelines, and cables, which may offer opportunities to study the related impacts. Institutes from other nations are invited to join the survey, where one option could be to select additional sites where human impact can directly be assessed, e.g. in the immediate vicinity of MPAs or windfarms.

Collaboration. Collaboration with other institutes is ongoing to ensure expertise for the ecosystem components sampled. For example, benthic ecologists and seabird specialists are regularly participating in the survey. An international collaboration, possibly with additional sampling sites in present/future areas of interest, is desired (see opportunities in SWOT table).

Other comments from plenary:

The objectives are prioritized. They originally focused on gadoid indices, but expanded over the years to include more aspects of ecosystem monitoring/ecosystem components (mainly types of sampling that don't require changes to the original sampling plan). Objectives developed over time. This is not really according to the flow diagram, but is often the case for most (all) ecosystem surveys. As objectives were originally focused on gadoid indices (but expanded over the years to include more aspects of ecosystem monitoring) not all other types of ecosystem monitoring can be added without losing the original scope and within the original time frame.

The survey can be combined with other survey series (also to increase funding security). It can be combined with a large-scale survey: Comparative studies with the IBTS have been carried out.

Survey results have been widely used, also beyond the original scope of generating gadoid indices.

3.4 The UK Western Channel Beam Trawl Survey (Q1SWBeam)

Summary description: The survey is carried out in a stratified random design, with a two stage selection procedure within a stratum to avoid overly clustered sampling within a given year to ensure that spatial heterogeneity within strata does not influence abundance information unduly.

The formation of the strata is initially based on fishermen's knowledge in the area. From some experiences on commercial vessels in the area it had become apparent, that it was possible to identify the location of catches quite precisely from the species compositional information in the region of Lyme Bay, and that these patterns were persistent over longer periods of time. Such spatially consistent heterogeneity suggested that a stratified approach to sampling would greatly increase precision of estimates.

In order to select stations at random the area is divided into 2 mile by 2 mile micro grids, however there was concern that picking the grids at random within a stratum could lead to clusters of stations in certain years, which may then have spatial effects as of course the strata are not entirely homogenous as an assumed. To reduce the possibility of excessive clustering strata are divided into a reasonable number of grids, with grids being selected at random in proportion to their relative size without replacement. Micro grids intersected by stratum or grid boarders are split into the respective subparts and one micro grid is randomly selected from each grid again in proportion to its area.

Although the main focus of the survey is the creation of indices for stock assessment in 2009 a number of other parts of the ecosystem were monitored including habitat discrimination using QTC and multibeam, sediment and benthos collection using a NIOS corer and mini-Hamon grabs and Spi-camera deployments and water column sampling using the Rosette and profiler which also incorporated nutrient work. Along with these gear deployments observations of seabird an mammals was also collected.

All of these observations were obtained at all stations, allowing for a full ecosystem dataset to be collected and analysed by station within the strata.

SWOT analysis

Strengths	Weaknesses
• sampling process is considered carefully • Objectives well defined (detailed focus on delivering abundance indices of commercially important flatfish) and prioritized (in favour of demersal fish) • A lot of ecological information (environmental drivers) were taken into account when defining sampling strata -> ecosystem(s) well defined • meets majority of MSFD monitoring needs • Probability based sampling, stratified random with restrictions (buffer to avoid samples very close in space) • sound ecological stratification	• not all ecosystem components are covered by survey (pelagic) • Designed with a detailed focus on delivering abundance indices of commercial demersal fish, determining sampling methodology (bottom trawling) to a large extent and making it difficult to incorporate other types of sampling within the limits of the current objectives • design is reliant on very robust gear • in order to carry out full ecosystem survey additional funding is required • A lot of tasks make prioritization difficult • funding not guaranteed
Opportunities	**Threats**
• new funding • new science • Proportional station grid might be a consideration • Specify the terminology about Primary Sampling Unit according to literature • A simpler design might make analysis easier.	• Funding • changes to policy • Not all customers are identified

SUMMARY OF PLENARY DISCUSSION FOR YOUR SURVEY BY HEADING

1. Survey design

- *Spatial and temporal coverage: Significant effort in using ecological information in the original design of the survey.* The survey is specifically designed to conduct an ecosystem assessment irrespective of its current use as mainly a fisheries survey for funding reasons. The assumption is that the interactions in the ecosystem occur on different spatial 'stages' habitats for want of a better word. The aim is to quantify the status and processes occurring in each habitat and applying it to the area of the stratum so that a predefined weighting can be assigned to each status observation / process to provide unbiased estimators of the central tendencies on the scale of the ecosystem providing an objective way to assess different impacts on the scale of the ecosystem.
- *Eco-components: In the full survey majority of ecosystem are covered with the notable exception of the pelagic component which at certain times of the year is an important part of the ecosystem.* Operational restrictions make this necessary, but the survey was designed to integrate with other monitoring resources, which are able to sample the pelagic resources effectively. Autumn is considered a more appropriate time to sample pelagics in the area for behavioural reasons and because this component relies heavily on summer productivity. The temporal separation complicates the objective of relating demersal components to pelagic components, but the stratified random design does allow for such comparisons though be it at a reduced level of precision. Fisheries acoustic information covering the pelagic component is currently collected on the survey and work is in progress to see if this information cannot be used to provide some information of the pelagic component of the ecosystem at the time of the survey in March. The main difficulty being the assignment of echo returns to species without species community information from trawl samples at that time of the year.
- *The complexity of the stratum design is excessive and fewer spatially less complex strata may be more appropriate and provide greater number of replicates to improve statistical power.* The stratification scheme was based on a multitude of information from different sources. The complexity of the shape of strata is derived from sediment maps which were interpolated from a widely spaced grid of samples so that the complexity may in fact be an artifact of the interpolation rather than the environmental complexity of the ecosystems and a review of the strata is overdue. However fish information at least suggests that communities are spread along gradients, rather than discrete clusters so that the exact location of stratum borders is less critical than the appropriate number of strata. At the moment there are 13 strata which are indeed greater than the number of strata required to provide the necessary level of precision on the two flat fish resources. However looking at other species or other ecosystem components suggests that these would benefit from different stratification schemes. The 13 strata represent the first approximation of the lowest common denominator (largest strata appropriate to a wide range of indicators).
- *Design and representation of the ecosystem: Fishing pressure is a significant part of the stratum design; however this may not be the only pressure and in weighting*

sampling by fishing pressure only could impact design if in future other human or environmental pressure increase. The survey design is in fact weighted by the availability of fisheries resources rather than fishing effort, although the two are obviously correlated. The reason for this is the need to produce fisheries information of a quality suitable for stock assessment rather than the consideration of fishing pressure more directly. Fortunately the weighting is by stratum (more sampling effort in areas of high plaice and sole abundance) and fishing effort is not uniform within those strata so that it is still possible to discern the effects of fishing pressure on the system. The stratified random survey design is sufficiently flexible that future changes in the distribution / type of anthropogenic pressures can be accommodated without out the loss of time-series information although it will result in a temporal change in the precision of estimates.

- *Process vs. status: The survey does not conduct direct process based observations.* Direct observations of process are difficult to conduct at sea; instead the survey relies on the random design to produce variation in the explanatory variables to indirectly infer process from status observations (correlations). In order to accumulate a sufficient sample size to make this inference may require several years' worth of observations and therefore requires the process itself to be independent of time though of course the actual rates can vary over time.

2. Prioritization

- *Fish priority: Given that the production of indices for stock assessment is the main funding source for this survey it is unsurprising that currently fish are the main priority.* Other forms of information are collected (hydrography, fisheries acoustics and multibeam for demersal habitat definitions), but heavily prioritized as to the costs because of limiting budgets.

- *Management relevance: The survey provides tuning information for two flatfish stocks in ICES Division 7e (one currently used in the ICES assessment process), but has little or no direct relevance on ecosystem assessment currently.* Given the recent and less than fully fledged discipline of ecosystem assessment in Europe this is less than surprising. With some additional funding to conduct regular ecosystem monitoring the survey certainly has the potential to provide an efficient means of collecting and interpreting such information. However, more of a problem for the survey is that fact that it is poorly aligned with the current consideration of ecosystem designation. It spans the confluence of two ecosystems and does not fully extend through either of them. Therefore the survey on its own cannot produce a complete ecosystem assessment and must ultimately be seen in the context of a wider ecosystem monitoring program.

- *Pressure weighting: Again weighted to fishing pressure, however this may not always be the most important pressure and regular analysis of the other ecosystem components is required to maintain the relevance of the survey*. Strictly speaking this is not true. The survey design has no inherent pressure weighting; this is associated with the distribution of sampling effort throughout the strata.

Current implementation of the design does indeed focus a disproportionate amount of effort on areas of fisheries resources, but this is due to the current misalignment of fisheries and ecosystem objectives due to funding. The design is sufficiently adaptive to change the weighting between strata without loss of time-series information.

3. Other

No survey should be looked at in isolation and as mentioned above. There are plans to develop a French, UK and Irish Celtic sea ecosystem monitoring program using pooled resources at different times of the year and looking at different ecosystem components at the appropriate temporal and spatial scales. In the context of such a program the weaknesses in this survey should be balanced out with the strength in other surveys and vice-versa.

4 Conclusions and generalizations from SWOT analysis of current ecosystem surveys in relation to ToR c) and d)

The SWOT analyses for each of the surveys were compared and some common denominators defined in order to develop generalizations for what to aim for and what to avoid when developing future ecosystem surveys. Not all points were considered relevant to ecosystem surveys specifically, but were applicable to surveys in general (for example gear calibration). The latter were discussed in plenary and included in the SWOT analyses but not discussed further in this report, as there are ICES WG's more experienced to deal with these issues. The main topic areas were in relation to the survey design and in the prioritization as a result of funding sources.

The aim of the report is to facilitate the development of ecosystem surveys in general, for which it is important to raise both the positive and negative aspects of specific surveys. These characterizations with regards to specific surveys should not be seen as criticisms of individual surveys or a judgement on their utility, especially because it was demonstrated that virtually all weaknesses had a diametrically opposed and mutually exclusive positive aspect when viewed from a different perspective. All the surveys have suitable ecosystem objectives for their ecosystems aims and weaknesses were judged against an ideological ecosystem objective, not all of which can be met on a single survey, but will need to be considered as part of a wider ecosystem monitoring program using. It is hoped that the conclusions will:

- better define the value of ecosystem surveys in the context of the ecosystem objectives, something that has been problematic for all surveys
- highlight the weaknesses and strengths of different survey design approaches in order to manage expectations of ecosystem advisors with respect to what each approach can and cannot provide
- help survey specialists to determine how they can most effectively improve their surveys when addressing a specific ecosystem thematic.

4.1 Survey design

4.1.1 Spatial and temporal coverage at sampling scales

The BESS and the PELGAS survey followed systematic survey designs (fixed stations) covering the entire spatial extent of the ecosystem evenly ensuring that ecosystem changes are observable irrespective of changes in the environmental dynamics and that the results are interpretable at the ecosystem scale. Clearly these are very desirable properties which have to be weighed up against the potential for introducing bias when the distance between samples in space or time is greater than the variability of ecosystem components. The PELGAS survey transect distance was specifically set under the evaluation of the variability criterion, but only for the fisheries acoustics component. To minimize the risk of introducing bias when transects and or stations are not representative of the surrounding area it is recommendable to investigate the spatial properties of all ecosystem components in order to determine the appropriate scale of ecosystem sampling.

Potential sampling bias in the sampled area can be altogether avoided by opting for random stratified designs, the approach taken by the other two surveys examined here.

In the case of the Q1SWBeam survey the conscious decision to apply such a random stratified design was made on the basis that the spatial variability of the abundance of fish occurred at finer scales than that which could be covered by a systematic design in the two week time frame available. In addition, the survey for fisheries management reasons does not cover an entire ecosystem, but rather the confluence of the Celtic Sea and Channel ecosystems so was unlikely to be applicable on the ecosystem scale so that greater importance was placed on the representative nature of the data than the absolute estimates of the results.

Because of the random nature of sampling the effects of anthropogenic pressures are sampled proportionally within a stratum. Effort allocation between strata however, is not proportional to the size of strata due to perceived differences in within strata variability. Consequently pressures are only covered proportionally within strata, but disproportionally between strata.

The GSBTS survey picks it stations randomly within fixed boxes so that samples are representative of the boxes, though there are some issues with increasing numbers of obstacle limiting the randomness of possible sample sites within each box. More fundamentally limiting though is the fact that the boxes cannot be seen as representative of the Greater North Sea, because they are first fixed (not systematic). Second, they were originally chosen to be free from obstacles to allow for full access, which on the other hand meant that at least originally they would have underrepresented pressures in the ecosystem as a whole. While the limited area of the Boxes naturally could not cover all available habitats in the ecosystem, their locations were chosen to cover a broad range of different habitats and water masses within the North Sea. As a consequence of its high spatial resolution within the Boxes, the GSBTS can provide insights into ecosystem processes and the effects of pressures on them but by itself these results cannot be scaled up to the entire area of the North Sea on an absolute scale. Therefore, the opportunities for using GSBTS data to fulfil or contribute to the data requirements for individual indicators need to be evaluated, particularly in combination with the somewhat complementary IBTS which has wider but rather coarsely resolved coverage of the NS ecosystem.

The timing of all these surveys is largely based on fisheries considerations, in other words to maximize the contributions to the fisheries information. For the BESS ice cover restricts timing of the survey and it is the consideration that the fish could not be observed in absolute numbers during other parts of the year (as also true for other ecosystem components) and survey timing is based on time-series of historic fisheries. The PELGAS survey is conducted at the time when the opportunity to determine the size of the age 1 Anchovy recruits is the highest, in order to provide precise catch forecasts. The GSBTS survey is timed to coincide with the IBTS Q3 survey so that the data can be related and the timing of the latter was already determined on the basis of fisheries management information needs. The Q1SWBeam survey timing was largely determined by ship availability, but of course this is also the time that maturity of a number of important commercial species in the area can be most adequately determined. In other words, none of the surveys used particular ecosystem processes beyond fish to determine the timing. On the other hand different ecosystem processes would require different timings so if only a single time is chosen, then special consideration should be given to the effects this will have on an ecosystem assessment.

Ecosystems do not have national boundaries, and none of the surveys examined here are restricted to the specific economic zones of a country, which adds significantly to their value as ecosystem monitoring. Both the BESS and PELGAS \ PELACUS are coordinated at the international level, pooling resources, sampling to a common design and sharing data resources to advance ecosystem understanding. This characteristic is vital for the process of developing a consistent ecosystem assessment as well as efficient monitoring. The Q1SWBeam and GSBTS survey are continuous across the respective national boundaries in the Channel and North Sea yet do not benefit from international collaboration. Pooling international resources would almost certainly enhance the precision of estimates and allow for wider scope to include more ecosystem components (Q1SWBeam) or allow for the examination of additional boxes that would make it more representative of the North Sea (GSBTS) In addition to a wider funding base international coordination can greatly enhance the value of ecosystem monitoring through sharing of expertise and experience.

4.2 Ecosystem components covered and expertise included

The range of ecosystem components covered in an ecosystem survey will greatly influence its capability to address ecosystem questions. Fundamentally an ecosystem survey should address all ecosystem components equally. This is a highly complex task, and judging by the experiences described at the workshop with current ecosystem surveys appears to be operationally inefficient. For example the need to obtain a snapshot view of mobile ecosystem components to minimize migration issues during the survey is in strong contrast with the time required on a single station to conduct detailed sediment sampling. If an ecosystem component or process can be shown to be stable over time, the current need for sampling is relatively low. However this is no guaranty that future environmental or anthropogenic pressures, for example the introduction of invasive species, will not alter this perception of stability.

Not all the surveys sample ecosystem components other than fish consistently throughout the time-series. Particularly the Q1SWBeam survey conducted only a single year of comprehensive integrated sampling. This may be an efficient way to understand process effects (see Section 4.3), but without a methodology to infer process from status observations that are regularly conducted fails to contribute to regular ecosystem monitoring. In any case for this to work effectively the work conducted should be much more process-focused and its planning and monitoring strategy more carefully examined from the outset to ensure it is fit for purpose. Here the ecosystem components sampled were more on the basis of interest in a single component rather than a focus on the interrelationship of different components.

A final consideration for integrated monitoring is the required expertise. Usually the number of survey participants is limited through resources as well as operationally through limited berths on vessels. For ecosystem component data to be most valuable it must be sampled in consistent ways with historic data, the nuances of which require expertise that can judge the best way to proceed when confronted with unusual conditions not described in the manual or operational issues require unforeseen adaptation of the sampling program.

The BESS has a rigorous training and quality assurance – quality control (QAQC) program in place that ensures the necessary expertise are at hand to conduct the survey and to maintain consistency through time and across vessels. Although expensive such operational planning is essential to get the most use out of the ecosystem surveys. The Q1SWBeam survey strategically planned the availability of expertise to coincide with the survey objectives, suggesting it is possible in highly diverse organizations to conduct such integrated work without the use of a training program, however whether this is operationally feasible on longer time-scales and whether it would deliver the necessary data consistency across years (conducted for a single year only) seems doubtful. The PELGAS survey conducts a significant part of its ecosystem work through cooperation with other institutes on an ad hoc basis which then supply the necessary expertise. The GSBTS involves external experts for benthic ecology and seabirds from collaborating institutions. Some of these partnerships have bedded in as long-term 'loose' arrangements, others are more fleeting. Although cooperation is highly desirable and when the results serve more than one partner it is efficient, the susceptibility of the program as a whole to fluctuations in the funding sources of the different partners leaves the ecosystem aspect of the survey vulnerable. Such susceptibility appears to be an inappropriate approach for a long-term monitoring program designed to provide information on the decadal scale (see also Section 4).

4.3 Process and Status observations

Previous discussions on ecosystem monitoring have largely focused on what to collect on ecosystem surveys, but the discussions at WKECES indicate that process considerations, the ability to describe the interactions in the ecosystem in order to predict future status, are just as important to ecosystem advice. How to collect ecosystem information (survey design) in order to most efficiently link the observations of different ecosystem components must be given formal consideration in ecosystem monitoring. This is true of surveys, but even more so applies to the ecosystem monitoring program of which these surveys form a part.

What we observe of an ecosystem is the result of a multitude of complex interactions and we attribute inherent strength and value to the diversity and complexity of these observations. Hence our desire / obligation is to conserve these systems. However ecosystems are more than their manifestations in structure and status. The underlying processes lead to these manifestations and they cannot be observed directly, but only through changes in status over time. In other words ecosystems are defined by their processes with status being the result of all previous processes. Therefore true ecosystem surveys must consider both process estimation and status estimation.

Both the PELGAS the BESS surveys dedicate some time to process observations in addition to the status monitoring information that they provide, but do not make process observations as part of their routine monitoring. Some might consider the lack process monitoring a weakness in an ecosystem survey. The reason why direct process monitoring on surveys is so rare is because it is very difficult to directly observing processes in the marine environment. It is however possible to infer process from status given appropriate sampling protocols and survey designs as is the case for the BESS and PELGAS surveys.

An extreme example of the classification of a survey as an ecosystem survey is the Q1SWBeam survey. Why is it being considered an ecosystem survey at all, when all it collects now is fisheries information? The reason is that its stratification scheme and survey design are specifically based on ecosystem considerations / habitats to provide the most accurate information on the abundance of some fish species possible given the resources, but could equally provide this information on other ecosystem components without altering the sampling design (maintaining time-series) with sufficient resources. In other words it is the consideration of the underlying ecosystem processes that makes it an ecosystem survey despite the fact that currently it only produces status observations for very few ecosystem components. In contrast, the GSBTS survey with much larger numbers of replicates is much more efficient at examining process, but instead fails to consider the process at the ecosystem scale, i.e. is not representative of the wider ecosystem, yet we also still consider it an ecosystem survey.

What these ecosystem surveys then have in common is that they try to understand the connections between different ecosystem components in the context of the environmental conditions. They all have very different ways of achieving this, with the Q1SWBeam survey using random variation to discern the underlying process while the GSBTS can be considered a much more process focused survey with the intent of applying the process component to the wider IBTS survey. The PELGAS and BESS surveys achieve their process aims by a mixture of the two approaches conducting some specific short-term process studies while embedding other process work within the formal monitoring or status work. The process work is used both to better understand the linkages in the ecosystem which helps improve the precision of status observations and their interpretation, but is also used to improve monitoring design and protocols. These components are essential to ecosystem surveys, but are frequently overlooked in the design and resourcing phase of ecosystem monitoring programs. Worse where they do exist they usually do so informally so that when resources become limiting they usually suffer first because their absence appears to have little effect on the monitoring program in the short term, but the long-term effects of missing a process or component can be more deleterious than reduced sampling size for example.

In WGISUR terms coordinated surveys, i.e. using survey platforms to collect many ecosystem components, but doing this to different designs in line with previous monitoring programs does not constitute an ecosystem survey because it does not consider process or how to link the different ecosystem components. In contrast, a fisheries survey that tries to link temperature with fish abundance has some ecosystem tendencies and including further ecosystem components or environmental drivers in the sampling will increase its value as an ecosystem survey. There are operational limitations to this approach which mean that not all components can be sampled at the necessary spatial and temporal resolutions at which they are important to the ecosystem suggesting a coordinated ecosystem monitoring program is required.

5 Prioritization and funding

The workshop was asked to examine different options for developing better prioritization for ecosystem surveys. Many fisheries surveys add ecosystem objectives mainly on the basis of ad hoc request with little information as to the value or the need for such data. This has often led to merely more data, rather than better or more useful data being collected. WKECES in the current situation can offer little insight as to how to set these priorities more appropriately beyond suggesting that any additional data that is collected must be able to link into the other data that is being collected in order to be of value to understanding ecosystem processes. We discuss various options for prioritization / weighting. Even for the **ecosystem surveys** discussed here fisheries funded work has been the priority with other components more or less haphazard sampled where external directives are not provided to survey scientists or resources are not made available explicitly. This at least in part explains the variety of approaches taken by the surveys examined here and highlights the difficulties with setting ecosystem objectives in the absence of a wider recognition of the role of ecosystem surveys. In general prioritization is primarily driven by finances, either by direct funding or through collaborations, with any spare capacity / unused contingency used to implement some work considered either important to better understand either an ecosystem or a monitoring process (survey design). This is not an ecosystem structure approach and in the long run is likely to be an inefficient way of monitoring, but it is what we are left with in the absence of clear ecosystem objectives. We describe some options for prioritization below.

5.1 Funding

All of the surveys examined at the workshop have their roots firmly in fisheries management advice, and the major priority is still to service the formal fisheries monitoring requirements, the exception here is the GSBTS which was designed to provide additional information to aid the interpretation of the IBTS data and complement them with detail on specific processes. The PELGAS and BESS are based on specific fisheries management objectives but have been considerably modified to provide a better understanding of the ecosystem, in the former specifically to address why recruitment fluctuates. These changes have largely been the result of the interest by individuals (bottom up approach) rather than an overarching policy driver (top down) and consequently the funding sources / priorities are somewhat misaligned with what one might consider the objectives of an ecosystem survey. The ultimate example of this prioritization of fisheries work is the Q1SWBeam which is specifically designed to deliver ecosystem information, but because of resource issues has reverted to almost exclusively carrying out fisheries work. This is not a criticism of the surveys by any mean rather it explains the limitations with respect to what is currently realistic in the terms of the development of ecosystem surveys in the absence of a wider overarching ecosystem monitoring approach that provides a more balanced distribution of long-term funds.

5.2 Relevance to management

Three out of the four surveys have significant direct relevance to fisheries management with a high priority. Beyond this though it seems that all but the BESS will play a role in the MSFD, however as described above this is currently not targeted, but reliant on what has been done. In other words no funding is associated with this role.

The BESS plays a similar role in the Norwegian and Russian ecosystem assessment process (not part of the MSFD) because of this and because it was established specifically to conduct ecosystem work it has a more balanced funding source, though still prioritized for towards fisheries work. Without a clearer understanding of how the information is to be used relevance to management beyond the generalization of ecosystem assessment is not possible and consequently prioritization is left up to the survey groups / individuals.

5.3 Pressure weighting

A number of countries within the EU (with respect to MSFD monitoring) as well as OSPAR have considered reducing number of samples collected in pursuit of the reporting requirements by focusing on the areas of highest anthropogenic impact. The argument for pressure weighting being that those areas or components of the ecosystem that are most threatened by anthropogenic impacts should be monitored most precisely as ecosystem changes are likely to occur here. If no changes are observed in the most heavily affected areas, then changes are unlikely to be evident in less impacted areas, thus pressure weighting is seen as an efficiency saving or prioritization.

The counter argument is that one may observe changes in impacted areas which are part of a wider ecosystem change driven by stochastic or natural environmental processes. In the absence of a balanced approach to monitoring one will not be able to distinguish those causes so may try to implement management measures without the desired response. More generally, to understand the effect of human impacts on the ecosystem require that the sampling design is more or less balanced with respect to the full range of the pressure gradients.

Lastly, although OSPAR has widely published that the greatest pressure on the ecosystem is that of fishing, this does not imply either that fishing is the greatest threat nor that this is the case everywhere. Fishing for example is highly unlikely to lead to biological extinction and thus should in most cases be fully reversible by cessation. In contrast contaminants may be present in low doses, but some are highly persistent and hence effective in a cumulative manner. In other words until the anthropogenic pressures can be quantitatively compared in terms of their threat to the ecosystem rather than on the basis of their spatial extent only it seems unlikely that an effective pressure weighting in the monitoring design could be implemented.

5.4 Collaboration (Interdisciplinary)

Ecosystem monitoring is a highly complex task that goes beyond the scope of individual expert groups, so that collaboration is an essential component of a monitoring program. What we consider as collaboration is a transient and mutually beneficial cooperation between the ecosystem survey and a discipline that is otherwise unavailable to the ecosystem survey. The survey provides a platform for data collection and the responsibility for allocating time to the work in return for access to the data. The collaborators funding is independent of the survey budget and has an independent aim. Having agreed to the collaboration the survey managers need to include the independent aims in the survey objectives with the risk that this may interfere in the monitoring objectives of the survey.

The PELGAS survey particularly has invested heavily on this resource of additional funds and expertise with significant success, but this may not always be the case. A less positive experience along similar lines was observed in the BESS program. For a while the funding system was changed to one individual disciplines were given the funds in order to come together to form a single survey. The experiment was unsuccessful because it led to incompatible demands from individual disciplines, whereas a single survey program was able to split up the available resources much more easily. Largely the difference is one of perception, but a fully financed panoptic idea allocating resources based on a clear priority list is much more easily implemented than trying to reconcile many divergent demands empowered by financial resources trying to bargain for higher priority.

The PELGAS survey has collaborated with industry to improve the efficiency of the survey, improve data quality and gain stake holder buy in. Such an innovative approach should be encouraged, but it does require a more formal up-take in the monitoring objectives and a firmer funding base if it is to become a routine part of the monitoring otherwise it will have impact on the time-series aspects of the survey.

5.5 How to prioritize?

Currently surveys are prioritizing on the basis of funding dominated by fisheries objectives. Whether in future these surveys serve a role in supporting other monitoring programs or whether they will be considered the basis of ecosystem objectives is fundamental to the future of ecosystem assessment and the continuation of these surveys. Either way, as ecosystem considerations become more important from a management perspective, for example through the advent of the MSFD, the role of these ecosystems surveys in monitoring must be made more formally and should include specific ecosystem objectives. EU national governments have used the information from these surveys to service the reporting needs for the 2012 initial assessment objective. In many cases it is however not clear to those making decisions on future surveys that they have done so or how, which means that it has not been possible to include those data needs as specific objectives in surveys so that there is no assurance that that data will be available in future without better coordination.

A more integrated and coordinated approach to ecosystem monitoring would ensure an improved scientific basis for management (process oriented monitoring), a more efficient, sustainable (better international coordination as exemplified by the IBTS survey for fisheries) and balanced approach to monitoring (coordinating work between different monitoring platforms to ensure the important ecosystem processes are covered temporally and spatially and results from all components of the monitoring program can be interrelated) and a more consistent ecosystem assessment methodology across regional seas. Establishment of a formal ecosystem assessments will allow the development of regional ecosystem monitoring programs which in turn will greatly aid the development of specific ecosystem objectives for these surveys and should bring the needed funding for fisheries ecosystem surveys to address the current imbalanced focus of fisheries resources. In the meantime it seems prudent not to attempt to develop spatially pressure weighted surveys where avoidable instead sampling proportionally or at least representatively should be the objective. Dealing with the conflicting demands of sampling different ecosystem components is much more difficult as the value of the individual measurements to the ecosystem assessment is unknown. However, a preliminary understanding of the ecosystem can provide important clues as to the main factors contributing to ecosystem function and stability. Prioritizing quantitative observations of these ecosystem specific factors would quickly enhance our basic understanding of the ecosystem while ensuring that at least in the crudest sense the ecosystem is maintained until such time that a more comprehensive prioritization is possible. Lowering priorities for ecosystem or environmental components that vary little in time or space could be seen as an appropriate measure to stretch the limited resources, but runs the risk that important changes are missed as changes in stable components are likely to be associated with much longer recovery times.

6 Improvement of ecosystem surveys (ToR c)

All the surveys examined here have distinct ecosystem characteristics and given the knowledge gained by examining them closely suggests that whether one considers these the best of a bad lot or the cutting edge of ecosystem surveys is entirely dependent on what one is hoping to achieve. All surveys could be significantly improved with unlimited resources, but an 'ideal ecosystem survey' appears to be a myth for even these incomplete ecosystem surveys are already running up against a large number of operational issues even without sampling all ecosystem components. Some spatial issues but particularly temporal considerations seem to make the ideal ecosystem survey unfeasible or at least highly inefficient.

Given then that all surveys are likely to fall short of the theoretical idea and all can be improved in some way what should be improved in each survey then goes back to issues discussed under prioritization, i.e. what money is available to make these improvements and which are most important. Discussions were held at the meeting with respect to each survey and information provided to each survey design team (not provided in detail here but see SWOT analysis). Mostly these surveys did as much for ecosystem understanding as is possible given the constraints of the funding and the objectives of the specific survey.

It is difficult to provide generalizations about improving ecosystem surveys beyond putting ecosystem processes at the forefront of objectives, because the individual characteristics of each ecosystem investigated differs, for example the effect of environmental conditions are very different. For most of the surveys seen here for example salinity is unlikely to be a major factor in driving ecosystem processes, whereas in the Baltic for example that assumption is unlikely to hold true. Therefore not only the survey design and the funding will determine the most effective way to improve surveys, but the knowledge of the ecosystem they are trying to cover will be vital.

7 Ecosystem surveys and the MSFD

The Marine Strategy Framework Directive is the EU's strategy towards ecosystem management. Therefore it will likely heavily influence the development of European ecosystem surveys and must be taken into considerations for the development of surveys where it applies. However it is clearly not universally applicable, nor does it necessarily describe the ideal scientific approach. It is the aim of WGISUR that those surveys that are conducted in EU waters should at a minimum be able to address the MSFD requirements.

The MSFD obliges member states to report on the ecosystems in their territorial seas. Ecosystem surveys clearly can contribute significantly to such reports, but neither WGISUR nor WKECES are charged with providing information in relation to the MSFD. Current requirements can be fulfilled in the absence of ecosystem surveys, in fact most of them currently are. However ecosystem surveys potentially provide a much more efficient way of fulfilling these requirements so that we took the approach that ecosystems surveys should be able to cover the ecosystem components on which there are reporting requirements which have been identified by WGISUR as being appropriate to carry out on fisheries surveys. The ecosystem surveys examined here generally have greater ambitions than meeting reporting requirement, and are focused on understanding the ecosystem, the why and how (Section 5.3). However WKECES also recognizes that at a minimum a good ecosystem survey should be expected to deliver the current MSFD requirements without the need to duplicate survey effort. We also recognize that the MSFD is more complex than the current reporting requirements and provides a brief history of our understanding of the MSFD as it was felt that this would be an important driver in setting objectives as well as a leverage point when arguing for funding and better ecosystem objectives for ecosystem surveys.

Monitoring and research requirements to meet MSFD obligations

Over recent decades, management of marine natural resources has shifted from the traditional single-species approach that supported the exploitation of key commercial species, to a broader ecosystem approach reflecting the need to safeguard all components of marine ecosystems and support a wider range of human activities (Garcia and Cochrane, 2005; Misund and Skjoldal, 2005). Within the domain of the European Union, ratification of the Marine Strategy Framework Directive (MSFD) in 2008 marked the culmination of this process. The MSFD requires "good environmental status" (GES) to be achieved for 11 "Descriptors" covering different aspects of marine ecosystems by 2020 (EC, 2008). The MSFD changed the basis for marine ecosystem research. Prior to 2008, scientists concentrated on making the case that an ecosystem approach to management (EAM) was necessary, but the MSFD implies widespread political acceptance of this point of view. So post 2008, researchers now need to focus on delivering the science required to support implementation of an EAM.

The MSFD stipulates specific milestones and provides a timetable for achieving these (EC 2008: Table 1). Across Europe the MSFD has been enshrined within Member States' national legislation, achieving the first milestone. To encourage integration in between the approaches that different Member States adopted, expert working groups were convened and charged with identifying the most effective indicators to meet the needs of the eleven Descriptors. The results of this process were summarized in the Decision document (EC 2010), which provides a list of 56 general indicators that Member States should use. The second milestone is therefore near delivery as Member States consider the specific metrics they will use to fulfil each indicator role, and determine metric target values that represent GES. Next, by July 2014, the necessary monitoring programmes should be in place to ensure that the data required to derive these metrics are available.

Early phases of MSFD implementation therefore concentrate on assessment of the status of marine ecosystems within European waters. But successful and effective implementation of the MSFD also requires basic research to understand the processes that underpin the structure and functioning of marine ecosystems, and most importantly how these processes are affected by environmental drivers of change and human pressures on marine ecosystems. A few examples clearly demonstrate the need for such elementary research.

1) Descriptor 1 of the MSFD states "Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions" (EC 2010). For each of the metrics and indicators that Member States propose to use, considerable effort has been expended in establishing target values that represent GES. Frequently, time-series analysis has been employed to identify historical indicator values at a time when anthropogenic impact on the ecosystem component in question was considered sustainable (e.g. Greenstreet *et al.*, 2011). But environmental change in marine ecosystem is now well established. We need to understand the processes by which monitored ecosystem components interact with the environment in order to assess whether targets based on historical data really do represent GES in today's and tomorrow's changing marine environment.

2) Indicators proposed in the Decision document to support Descriptor 4 "All elements of the marine foodwebs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity" (EC 2010) tend to focus on structural elements of foodwebs. The Decision document also states "This descriptor concerns important functional aspects such as energy flows …… of food webs", and goes on to acknowledge "Additional scientific and technical support is required, at this stage, for the further development of criteria and potentially useful indicators to address the relationships within the foodweb", implicitly recognizing the shortcomings in the suite of indicators currently proposed. Descriptor 4 is not alone in this respect. With regard to Descriptor 11 "Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment", the Decision document is equally frank, recognizing that "Additional scientific and technical progress is still required to support the further development of criteria related to this descriptor, including in relation to impacts of introduction of energy on marine life, relevant noise and frequency levels". We can only develop better foodweb and energy level indicators if we improve our understanding of how foodwebs operate and how the introduction of energy, such as noise, into the marine environment affects the organisms that reside there.

3) Explicit in the 2016 and 2020 milestones (Table 1) is the need for Member States to take corrective measures where the initial assessment suggests that parts of the marine ecosystem are below GES, so that GES might be re-

stored by 2020. Determining appropriate effective management measures can only be achieved if we understand processes by which various human activities impact different components of marine ecosystems. In many instances conceptual theoretical computer-based models will be needed. Such models can be used to explore how the different indicators behave under varying environmental and human pressure conditions. They can be used to simulate changes in "status" from 'pristine' through to 'overexploited', to identify the 'sustainable use' condition, and determine the permissible level of human pressure commensurate with achieving and maintaining GES under varying environmental circumstances.

Full implementation of the MSFD therefore requires a combination of different scientific activities. Basic marine survey work is required to collect the wide range of data necessary to assess and monitor change in the status of major components of marine ecosystems within the European Union domain. But elementary research to enhance our understanding of how marine ecosystems work is also essential in order to interpret correctly the changes we observe, and to ensure that the actions we take to manage our marine ecosystems are the right ones.

8 Conclusions

The Workshop reviewed current ecosystem surveys, but it became rapidly clear that all these surveys were adapted fisheries surveys, so the question arose 'what makes a survey an ecosystem survey'? In its simplest form it is any survey that goes beyond the question of 'what is out there?' and asks, 'why is it out there?' The workshop concluded that the definition of an ecosystem survey could be one that considers ecosystem processes as an integral part of the survey design and planning. An ideal ecosystem survey would encompass all ecosystem processes as well as monitoring of ecosystem status, but it would appear that there are insurmountable operational and temporal barriers to the ideal ecosystem survey so that one should think of 'less than complete' ecosystem surveys as a vital part of an 'ideal ecosystem monitoring program'.

The WKECES case studies demonstrate that surveys that formally primarily served fisheries management purposes can be adapted to form the backbone of an effective ecosystem monitoring program. The most important initial consideration when adapting surveys is not which ecosystem components to add, but how to add them as to maximize the improvement in ecosystem process understanding.

Ecosystem surveys should be based on robust (statistically) and preferably adaptable sampling designs, the development of which must include the evaluation of existing data / knowledge to assess temporal and spatial scales of variability of order to assure efficiency and effectiveness. There are a number of different effective options to achieve such monitoring aims all of which have their respective strengths and weaknesses. The best design in a given situation is a function of the characteristics of the ecosystem, especially the spatial and temporal gradients in variability, the management requirements / priorities and scientific objectives.

The recurring question of the prioritization of specific survey aims (which information to collect) under increasingly restrictive budgets is a difficult one. The workshop considered a number of these and their benefits and disadvantages. Interestingly an ideal ecosystem survey does not have to make these compromises, but it is a pipe dream. Given then that we are looking for something less ideological, weighting by ecosystem component variability, survey resource contribution (usually fisheries), anthropogenic pressures (MSFD) or by common aims with others (collaboration) are all legitimate forms of prioritization, but require a more detailed list of objectives and more importantly some perception of the longevity of the objectives to make the appropriate decisions. For most surveys these detailed criteria are only met for the fisheries component which is generally why this is a dominant driver of the ecosystem surveys examined here.

Ecosystem monitoring is still in its infancy in many ways and survey scientists need to be aware of the evolving policy drivers and take the opportunity to influence policy development by advising managers on potential future questions and how they can be addressed using ecosystem surveys .Ecosystem monitoring goes beyond the requirements of the Marine Strategy Framework Directive, but should be seen as at least addressing the requirements of the current legislation. To that aim ecosystem assessments on the regional scale would be greatly improved by an internationally coordinated ecosystem monitoring approach, which considers ship time, laboratory facilities and scientific expertise as a pooled resource and provides comparable information on the regional scale.

Monitoring an ecosystem will always be more expensive than monitoring a component of an ecosystem (fish) or data collection for a small-scale specific question (wind farm placement). Currently, government funding for ecosystem monitoring work is difficult to attract because funding is frequently already parcelled out for single discipline monitoring, which makes getting to an agreed common program very difficult on the regional ecosystem scale. Funding bodies and customers must be made aware of what ecosystem surveys can deliver and how the integrated approach adds considerable extra value to the ecosystem management approach compared to separate monitoring programs.

More efficient and particularly automated sampling methodologies should be developed, investigated and tested to ensure effective use of resources, but these developments must also consider time-series and data quality aspects.

WKECES found some inconsistencies / difficulties particularly with respect to the ordering of certain tasks in the WGISUR flow diagram designed to assist in the development of ecosystem surveys. Some revisions / clarifications to this diagram by WGISUR would be considered helpful.

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Appendix 1: All comments provided by members of the workshop following the presentation of each survey.

Not all of these were necessarily discussed in plenary and the purpose of the appendix is completeness sake and to provide the survey managers with as much information as is possible to improve their surveys. Comments were made in the context of the ideal ecosystem survey and do not necessarily consider the operational constraints, aims or objectives of the individual surveys, thus should not be interpreted as criticisms

Barents Sea

Strengths

- A number of funding streams (could also be a weakness)
- Ship inter-calibration of ships before series started
- Opportunities to carry out additional science, platform for science
- Exchange of staff between ships and areas
- Timing for key species
- Time-series data
- Published data
- Collaboration provides a ‘true’ sea wide assessment. Not restricted to regional waters as many surveys are
- The introduction of additional ecosystem elements
- Spatial coverage
- Timing, summer (limited ice coverage better weather, less operational downtime)
- QA procedures
- Data availability, collaborations
- This survey has momentum and a lot of support
- DESIGN: original objectives largely based on the objectives of previous targeted fishery surveys until 2010, BUT definition of ecosystem objectives in 2011 + influence on original objectives allowed
- DESIGN: uniformly spread sampling grid ensures good coverage of the total area
- DESIGN: timing optimized in relation to primary goals (and least ice coverage)
- DESIGN: expertise needed is defined, and ensured by training programmes (mainly NO) or keeping the crew constant over years (mainly RU)
- Internationally coordinated (NO – RU)
- USE OF RESULTS: NO – RU agreement on mutual use of the data
- USE OF RESULTS: delivery of important data for single-species stock assessments, in this case especially cod and capelin.

- USE OF RESULTS: two-stage quality checks (1. immediately after sampling at sea, by experts entering data into databases and by quality check software; 2. on shore when analysing data)
- USE OF RESULTS: besides stock assessments, results also widely used for projects, Barents Sea management plan, publications …
- Area covered is critical for understanding effects of climate change in the Arctic, where global change is expected to be particularly intense. Coverage already allowed detecting climate-related shifts in distribution of key species in the system.
- Huge area covered; enormous commitment of resources in ship time and personnel from Norway and Russia (see also weakness)
- Obtaining data for of many ecosystem components
- Optimal timing in many respects (August-September) – ice coverage is close to minimum
- Process understanding approached, e.g. through stomach sampling of cod
- Data used in various stock assessments (e.g. cod, capelin, polar cod)
- Procedures based on experience from prior surveys that were then combined in the ecosystem survey
- Opportunity to create solid basis for integrated ecosystem assessment in the Barents Sea
- Website for the survey (www.imr.no/tokt/okosystemtokt_i_barentshavet), which also includes Sampling Manual and Survey Report.

Weakness

- Massive area covered could be an issue
- Possible conflict of objectives as no priority of objectives are set
- No overlap during the time-series
- Uncertain variance estimates (is that a real issue?)
- Timing not optimal for all parts of the ecosystem
- Massive datasets not integrated and easy to use
- Systematic sampling, lack justified variance estimator for abundance estimator
- No "signature" of responsible sampling person for the different tasks in the lab (for example subsampling, length measurements)
- No comment field in the electronic station protocol
- Introduction of more ecosystem elements (spreading the resource thinly) against a backdrop of a reduction in resource
- Several project drivers
- Fisheries driven funding very inflexible
- Calibration between survey vessels (Norwegian vs. Norwegian vessels and between Russian and Norwegian vessels)
- No infaunal survey carried out
- No habitat acoustic surveys undertaken
- Accessibility of data

- Although two countries collaborating in full still very difficult for the different vessels to operate in each other's waters
- Pressure assessments
- EXPLORATION: a lot of ecological information available on the Barents Sea, but seemingly not used for defining sampling strata
- EXPLORATION: same for information on anthropogenic pressures
- DESIGN: objectives largely based on the objectives of previous targeted fishery surveys, and priority remains here
- DESIGN: due to priority of timing the survey when commercial fish stocks can be maximally documented, some other organisms/processes (as peak in planktonic production) are consistently missed
- DESIGN: Although internationally coordinated (NO – RU), restrictions on entering each other's EEZs restrict possibilities for intercalibration (no overlap in survey areas; some intercalibration has taken place before the ecosystem survey started)
- DESIGN: gear specification not properly followed -> affects standardization, intercalibration, continuity, and comparability of results between and within years
- USE OF DATA : data currently difficult to access for mega-analysis (of different ecosystem-components/species/trophic levels together)
- Dependent on huge commitment from both countries involved (ca. 70 science crew form Norway alone)
- Integrated objectives for the whole ecosystem were not formally developed before 2011
- Ship time has been reduced significantly (*from ca. 200 days to ca. 130 days – numbers taken from figure in presentation*)
- Restrictions to the respective national EEZs prevents intercalibration of equipment and procedures

Opportunities

- A lot of ship time
- Large resource that could be distributed differently to cover 'whole' ecosystem
- Overlap ship areas
- New database/data warehouse is being developed
- Further research due do to being 'data rich' able to address now \and in future many ecological questions. The ability to address truly temporal patterns in relation to climatic change etc. etc.
- To assess the ecosystem at a functional level
- To introduce further elements (benthic infaunal samples)
- Underwater camera surveys, visualize the habitats, how fish interact with their habitat
- Integration of pressure assessments
- Possible platform for process studies

Threats

- Human impacts
- Decreased sea time
- Decreased funding (data analysis)
- Some missing elements of the ecosystem, limits the trophic interactions that could be investigated
- If either Russia or Norway decide to no longer participate
- Annual change of a portion of the science personnel involved from IMR
- (*Rather a challenge, and possibly one for all ecosystem surveys*): Establishing a comprehensive database for all element of the survey

Other comments

- Make procedures for representative subsampling an important issue
- Conduct experiments to investigate spatial correlation function as a function of lag, including nugget effect (diurnal stations)
- Make “signature” for sampling task responsible
- Make general comment filed on the station protocol

PELGAS / PELACUS

Strength

- DCF funded, large range of pelagic ecosystem observations possible
- adaptive strata for biomass estimation
- additional time can be used carry out ‘special aims’ within set objectives at the end of the survey, e.g. testing methodological approaches, process studies on fish behaviour, video, egg and larval experiments, drifter studies for larval drift, test of new sampling gear (video, acoustics, optical, fishing). Details are decided on and can be adjusted during the first part of the cruise with the primary survey
- Almost Equal coverage
- Modelling of spatial correlation
- Focusing on the pelagic community
- Anchovy clearly prioritized
- Covers important life-history period (spawning).
- Good cooperation with fishermen
- Good sampling procedures for other ecosystem components and processes as well.
- EXPLORATION: Objectives well defined, and including monitoring of many aspects of the pelagic ecosystem (biotic and abiotic), and are clearly prioritized (in favour of acoustics)
- EXPLORATION: Resources and constraints are defined
- DESIGN: methods to match objectives, timing of survey, expertise needed -> all defined
- USE OF RESULTS: samples that are currently not being processed are stored

- OTHER: Internationally coordinated, common database (under construction)
- Long-time-series
- results uses in assessment
- Foodweb data (stomach and isotopes)
- commercial species are investigates on the different stages (egg, larva, adult)
- Full coverage of the western French (and Spanish) shelf area, and even a bit beyond the shelf break in the south that confirms that there are little anchovies
- Very rich output in terms of publications of various types! => possibility/idea to combine in a CRR, next year.
- Zooplankton data and hydrography/chemistry available for fixed stations
- Systematic transect survey, approximately equal distance (random start?) 12 miles between transects during day. Modified design with longer transects to do egg collections since 2011. 6–8 biol. samples per transect. At night between transect sampling for plankton. Working on estimation of spawners from egg survey data and modelling of drift.
- Long dataset to assess what any impacts of reduced survey extent/time
- Developed/ing database containing egg distributions and other factors 2003-present
- The ship is fully occupied 24 hours a day (no spare berths). Opinion is that number of observations could not be reduced
- Drift buoys deployed to monitor drift and validate 3dimensional model
- Collaboration between two countries has increased the scope (area covered) of the survey
- Assessment of birds, mammals, turtles, sharks, floating litter and plankton
- historical development of the survey (earlier investigations presents)
- logical survey border (depends on the nature factors)
- results uses in assessment
- logical strata border for stock size calculation
- quick-access report (1st July)
- involve of students and PhD (future staff)
- consort survey with commercial vessels
- multi-purpose survey
- good technique equipment
- commercial species are investigates on the different stages (egg, larva, adult)

Weakness

- poor assessment of rest of ecosystem
- man-made pressures not identified well
- DCF funds partial
- must be carried out in spawning season (loss of vessel)

- does the timing allow the tracking of a change in spawning season?
- trained staff
- possible bias with sampling south to north
- you need a large vessel to carry out the survey at the current resource level
- no free time in the 42 days for extra work
- No stratification?
- Target strength difficult
- Requirements for providing fish abundance index must be balanced with other activity.
- Design could lead to overestimation of the fish stock, since there is a certain northwards migration following the progression of survey transects.
- EXPLORATION: Objectives well defined (distribution, abundance, recruitment, solving methodological issues, community structure, behaviour, ecosystem monitoring) but only focused on pelagic ecosystem and mainly on one species (anchovy) / species group (pelagics)
- DESIGN: A lot of ecological information is available, but given that fixed transects are fished every year (evenly interspersed) this information does not seem to have been used for defining ecosystems/ecosystem components (if applicable for pelagic?) and was not incorporated in the sampling design
- DESIGN: Same for fishing pressure (although it is regarded to be of minor importance compared to the environmental drivers)
- DESIGN: inshore communities/ecosystem(s) not sampled
- DESIGN: Several biological parameters (stomach contents, fat contents, fecundity, parasites, genetics) only sampled opportunistically, or only by PELACUS (stable isotopes)
- DESIGN: for extra work the general objectives are set, but not in detail. Exactly what will be sampled where is decided on board after the main objectives have been fulfilled.
- USE OF RESULTS: wide range of databases/Excel files/text files for different types of data, not yet combined in a common format or database
- USE OF RESULTS: not all samples are currently being processed
- Data storage. Acoustic database
- Linking with demersal surveys
- Zooplankton data obtained (partly on regular stations, partly opportunistic). But so far no link between anchovy abundance / recruitment and zooplankton abundance is being analysed – although zooplankton is expected to be a crucial factor in the recruitment.
- Anchovy clearly prioritized
- 30 days to cover highly migrating species in a survey area
- Fisheries funding inflexible
- No other pressures (riverine inputs) taken into account
- The survey cannot go into shallow inshore waters and could possibly miss important information there.

- No habitat mapping techniques utilized in the survey, no links to habitat other than pelagic made
- Pressure factors (natural pressures)?
- Time restraints (Anchovy spawning time)
- No data on the bottom community (it is important part of ecosystem)
- complication with staff (possible it affect data quality?)

Opportunities

- possible expansion of communities it can assess
- 23 scientists available to carry out more data collection
- opportunistic sampling aims
- Idea to combine all the data eventually, at least initially through overlay of the datasets on maps: Pelagic fish, zooplankton, hydrographic data, water chemistry. Ultimately chance to parameterize ecosystem models, also supported by process studies – e.g. with Lagrangian drifters to inform on pathways of egg/larval drift.
- Addition of habitat information to understand the system further
- Utilization of pressure data to help explain observed distributional patterns and movements of Anchovy
- The assessment of microplastics from plankton tows

Threats

- limited to pelagic ecosystem
- national funding
- EC funding
- succession planning for experience
- you need a large vessel to carry out the survey at the current resource level
- loss of commercial vessel collaboration
- if funding was cut what is the impact?
- The institute supports the survey and also the process studies attached to the core survey. This sort of support is needed to address specific questions on ecosystem function, but are more difficult to find consistent funding for. (*It should be discussed in plenary and particularly with Jacques how this is best presented in order to be most beneficial long term.)*
- Reduction in days
- The ability to collect additional information outside the current remit
- Continued inclusion of fishermen in the sampling programme and so reduced ground-truthing of acoustic marks

Other comments

- Make procedures for representative subsampling an important issue
- Scanmeter (video in trawl) to improve TS measurements

German Small-scale survey

Strength

- time-series
- different parts of ecosystem are sampled over the North Sea
- combined with other survey series (funding security)
- within boxes random station selection and random direction
- peer reviewed papers published
- Monitoring of gear behaviour
- Replicates within "primary sampling unit"
- Long-time-series
- International coordination
- Process studies
- Randomized design (but with some subjective selection of hauls to ensure coverage of the area of the box)
- Some observations between boxes (e.g. seabirds).
- Interesting method for studying processes.
- Can be combined with large-scale survey.
- Good output of scientific papers on different topics.
- Several institutes involved, each with their own specific expertise
- EXPLORATION : objectives originally focused on gadoid indices, but expanded over the years to include more aspects of ecosystem monitoring/ecosystem components (mainly types of sampling that don't require changes to the original sampling plan)
- DESIGN : hauls within a box are distributed over the sampling days both in time and space
- DESIGN : objectives prioritized
- climate change effects documented
- TEST : vessel comparison was carried out (1986) before official start of the survey (1987)
- Results widely used, also beyond the original scope of generating gadoid indices
- Quite enough suitable for quality estimations
- Different trophic levels investigate in the same time
- Benthic components (infauna and epifauna)
- Additional components (litter, plankton and seabird observations)
- Standard gear (same as the IBTS)
- Standard sampling techniques (grabs and benthic trawls)
- Comparative studies carried out (with IBTS)
- Staff training programme, species identification
- Ability to examine trophic interactions (fish and benthic communities)

Weakness

- Different vessels and gears for all area

- Are they covering the whole ecosystem of the North Sea?
- Small area, many replicates: Many hauls do impact abundance?
- 2 vessels (need for intercalibration)
- Different sampling intensity (different tasks) in the different boxes
- Objectives developed over time. This is not really according to the flow diagram, but is often the case for most (all) ecosystem surveys.
- Is the objectives prioritized?
- Irregularities in the time-series., i.e. time-series of different variables varies between boxes and data variables measured.
- EXPLORATION : as objectives were originally focused on gadoid indices (but expanded over the years to include more aspects of ecosystem monitoring) not all other types of ecosystem monitoring can be added without losing the original scope and within the original time frame
- DESIGN : ecosystem is defined as ‘North Sea’, no(t a lot) ecological information seems to have been used to define strata, same for anthropogenic pressures (especially fishing pressure)
- DESIGN : design based on fixed boxes (that should represent the range of habitat types) that are far away from each other makes it difficult to pick up ecosystem changes/processes in between these boxes, additionally some boxes have been impacted more than others over the time-series but this cannot be extrapolated to the North Sea scale
- DESIGN : random towing direction without recording current speeds and directions clearly has advantages, but also the major disadvantage that these parameters cannot be used as a factor in any analysis
- Weak suitable for quantity estimations (fish at least).
- Different gears on vessels
- The place of “boxes” could not reflect all process in ecosystem
- Different investigation in different years in different boxes (e.g. fish stomach, infauna)
- There is no “boxes” in some areas (3, 4, 5)
- Additional programmes not consistent between vessels
- Area coverage (small survey areas) how to extrapolate to a larger scale
- Introduction of operational risk (if all tows are in a poor direction (against prevailing conditions) then may not be able fish or catches may be reduced
- No acoustic surveys (production of habitat map) in relation to the benthic communities and fish communities. Provides a link to the benthic communities

Opportunities

- more data could be collected if resource available
- would it be better to use large ship for all 12 boxes?
- Plankton sampling coupled with CTD sampling (LOPC or plankton nets).
- Collaborations with other countries
- Integration with other long-term datasets

- Incorporation of acoustic habitat mapping techniques to use a long side fish distribution patterns within the survey areas
- The introduction of pressure assessments. (fisheries VMS data)
- Underwater video (visualize the habitat, how fish interact with their habitat)

Threats

- resource hungry
- human impacts within boxes
- environmental factors impacts on whether you can fish or not if you continue to fish in random direction
- Existing boxes being encompassed within wind farm construction, MPA's
- Funding
- The relevance to stock assessment, if limited will funding continue?

Other comments

- Make procedures for representative subsampling an important issue
- Random sampling with random direction: Let sampled starting point be on the middle of the trawl transect, thus reducing impact of constraints like pipelines.
- Examine effect of shorter tow durations

Q1 SW BT survey

Strength

- very logically planning of the survey
- sampling process is considered carefully
- survey data use in the further work well
- quite dense sampling points in the survey area
- different equipment using in the survey and high-tech level
- Some deliverables are defined (fish stock assessment?)
- Ecosystem survey – specific processes/aspects can be understood
- EXPLORATION: Objectives well defined (detailed focus on delivering abundance indices of commercially important flatfish) and prioritized (in favour of demersal fish)
- EXPLORATION: Resources and constraints are defined
- DESIGN: A lot of ecological information (environmental drivers) were taken into account when defining sampling strata -> ecosystem(s) well defined
- DESIGN: As areas with different fishing pressure (the main pressure in this area) more or less consistently correspond to the different ecologically homogeneous zones (habitats), fishing effort was inherently taken into account in the spatial sampling design
- DESIGN: methods to match objectives, timing of survey, expertise needed -> all defined
- TEST : test haul performed at beginning of every survey

- Flexible
- meets majority of MSFD monitoring needs
- sound ecological stratification
- Stratified sampling that seems appropriate in order to improve precision
- Probability based sampling, stratified random with restrictions (buffer to avoid samples very close in space)

Weakness

- survey border are restricted by border of administrative ICES Subarea VII e. It covers some part of open sea and not based on geography, water mass etc.
- not all ecosystem components are covered by survey (pelagic)
- Ecosystem objectives not clearly defined at outset
- A lot of tasks make prioritization difficult
- PSU defined in an untraditional way
- Design is a bit complicated, requires expert knowledge to produce random grid
- DESIGN: Designed with a detailed focus on delivering abundance indices of commercial demersal fish, determining sampling methodology (bottom trawling) to a large extent and making it difficult to incorporate other types of sampling within the limits of the current objectives
- OTHER: Not internationally coordinated (yet)
- OTHER: funding not guaranteed (yet)
- If stratum changes for a part of ecosystem (e.g. pelagic) then is your current stratum/station appropriate,
- possible too many strata
- not able to monitor all MSFD descriptors (but most)
- design is reliant on very robust gear
- pressure other than fishing could impact strata
- in order to carry out full ecosystem survey additional funding is required
- Fisheries data important
- Scope to change limited?
- Autocorrelation does not appear to be an issue?
- Strong positive autocorrelation between neighbour observations may indicate that systematic regular sampling is better than random?
- Possibly over-stratified. May be efficient for some species but possibly inefficient for some objectives. Small sample sizes in strata can lead to bias in ratio estimates, for example for estimates of proportions at age.
- Allocations of samples to strata is far from proportional to area.
    - This results in more complex estimators for post-strata that cross smaller original strata because sampling locations within post-strata have unequal inclusion probabilities.

Opportunities

- new funding
- new science
- Proportional station grid might be a consideration
- Specify the terminology about PSU according to literature
- A simpler design would make analyses easier.

Threat

- Funding
- changes to policy
- Customers for MSFD

Other stuff

- Make procedures for representative subsampling an important issue

Appendix 2: Full reference list of publications derived from the GSBTS survey.

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Appendix 3: Full reference list of publications derived from the PELGAS survey

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