

JOINT



REPORT

**Assessments for management of living marine resources
in the Barents Sea and adjacent waters
– a focus on methodology**

The 16th Russian-Norwegian Symposium
Sochi, Russia, 10-12 September 2013

Edited by
Knut Sunnanå, Yury Kovalev, Harald Gjørseter, Espen Johnsen, and Evgeny Shamray

Institute of Marine Research - IMR



Polar Research Institute of Marine
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Preface

Marine scientists from Norway and Russia met in Sochi, Russia, from September 10 to 12, 2013, in order to present results and discuss items related to “Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology”. About 50 authors contributed to about 23 presentations at the symposium. In addition there were two keynote presentations, and 5 posters (Appendx 1 – Program of “The 16th Russian-Norwegian Symposium in Sochi, Russia, 10-12 September 2013”).

The works presented were divided in three sections: Survey strategy and methodology, Index calculations and Stock assessment methods, with 13, 7 and 8 contributions respectively. The introductory keynote presentation focused strongly on the handling of variation and uncertainty in the data sampled for assessment, both from catches and from surveys. Especially the focus was around how much sampling is actually enough. Also, the role of data versus lack of data was treated and it was clearly stated that data are only in support of assessments and models. New algorithms and computer programs to estimate the catches at age from samplings of catches and landings were presented. The main goal of the new development was the ability to calculate the variance and the error of estimation for the data cells.

A central problem in fish stock assessment is to split the data on ages. Age is determined by using bony tissue, mostly otholits, and shell. The sampling rate for sub sampling of age in samples from catches or surveys were treated using various methods, with a special focus on the term “Primary sampling unit” (PSU) in what the presenter called a design based method. Several weighting procedures were evaluated and the key note presentation concluded that a mix if new and old methods gave a good result with a clear reduction in sampling rates for age. The last part of the key note presentation was about handling of uncertainty in fish stock assessments due to sampling errors. A comparison of two assessment methods was used to illustrate effects, and comments were given as to how IMR and PINRO could coordinate effort to give better solutions to the stock assessments. During the theme session on “Survey strategy and methodology” the presentations focused on three themes. The first was gear technology and the impact on results from surveys, where observation during scientific trawling and the ability to observe directly on the sea bed was two focus themes. The second was development of survey and sampling strategies, where the ecosystem survey in the Barents Sea and its relation to developing a monitoring strategy was elucidated. To some extent the strategy applied today turns out to be reflecting topography and environmental variability in the survey areas. It was also shown that the ecosystem presented data sufficient to perform an integrated ecosystem analysis involving a wide range of sampled parameters. However, a strategy for the future development of surveys is needed, and especially the development of multi-purpose ecosystem based surveys needs to be developed further. The joint Russian Norwegian ecosystem survey was presented in detail. Especially the sampling strategy for the measuring of first year fry (0-group) abundance was treated in further detail, indicating that reduced sampling may give the same precision as today.

Thirdly, focus was put on examples of assessments using particular surveys as basis, e.g. euphausiids, Harp seals and Greenland halibut. Krill is a major plankton biomass in the Barents and Norwegian seas and there is a time series from 1980 to be analyzed for biomass dynamics and production potential for predator stocks. There are, however, methodological challenges in using this data series and to develop the future work on this theme. An important predator biomass in the Barents sea is the Harp seal. Although a large part of the reproductive stock is found close to Greenland, this stock is still having an influence on the Barents Sea. Estimation of the pup production is of vital importance and this is done by aerial surveys using counting and photographing of the whelping areas on the ice off East-Greenland. The data are put into an age-structured population dynamic model to assess the stock situation, indicating a growing stock for the last 40 years. Also in the White Sea similar investigations are performed, using infrared photographing, and this part of the Harp seal stock produces a low number of pups at present. Sexual dimorphism in the stock of Greenland halibut needs special attention regarding survey design and calculative methods, and these were investigated using selectivity experiments onboard a Russian research vessel.

During the theme session on “Index calculations” the focus was on uncertainty and variance calculations, illustrated by herring, capelin and stomach sampling in addition to general calculations of survey indices. The stock of Norwegian spring spawning herring is analyzed using a VPA that is tuned by surveys covering the stock. A new method development in the index calculation is introduced by using a model that calculates variance of the estimated fractions of size and age groups. This gives estimated standard errors of the resulting abundance and biomass estimates of the herring stock. For the cod stock in the Barents Sea a new approach to index calculation was presented, using probability based estimators, giving estimates of variance and diagnostics to indicate improved design under certain assumptions. Allocating acoustic abundance measures to the correct species and size group is a challenging problem in trawl acoustic surveys, and this problem was the focus of a work dealing with an automated procedure in area stratified surveys combined with Monte Carlo simulations and bootstrap approaches to give point estimates with corresponding estimates of variance. Some of the novel methods have been brought into the computer program “S2D StoX” that was presented with the potential to be a standard stock index calculation program. The approach is based on the data base infrastructure called Sea to Data (S2D) and is a joint data base approach between IMR and PINRO, also implemented on the research vessels. The capelin in the Barents Sea is estimated by use of an acoustic survey in the autumn and a new development was presented where the distribution of capelin is simulated using a model approach, and the quality and uncertainty of the assessment process is evaluated in relation to the simulations. The relationship between cod and capelin is the most important in the Barents Sea and 30 year of sampling of cod stomachs give a large set of data to be used in the calculations of stock indices. There are methodological challenges and these are solved in cooperation between IMR and PINRO, and there is also a strategic development of methods to be used in the future.

In the section on “Stock assessment methods” the focus was put on assessment models based on catches and surveys, and also harvest rules and assessment quality were considered. A statistical assessment model (SAM) was presented and the advantages related to uncertainty estimates were in focus. Further, a presentation gave an overview of some possibilities to handle mortality, exploitation patterns and survey catchability in an assessment process. Management of capelin in the Barents Sea is done by an assessment model that also includes cod. A retrospective evaluation of this assessment show that improved knowledge of the cod stock, given by more recent assessments, would have altered the advice for quotas on capelin. The harvest rules for the capelin management have also been tested by simulations and inclusion of herring in the model, and a number of recruitment function were tested and the best were selected for an updated harvest rule evaluation. Another important, and introduced, species in the Barents Sea is the King crab, and this species was also presented through a model concept. Estimation of the parameters in the model was done using a Bayesian approach and a recommendation to use this model in future assessment was given. A work on improving the assessment model of cod in the Barents Sea was presented and the conclusion was that the assessment was sensitive to some of the parameters in the XSA model approach. It is recommended that this be investigated further. The final presentation was about Greenland halibut and the problems related to uncertainty of the age reading of the species. These difficulties especially affect the evaluation of the spawning stock size, as this is dependent on the age of maturity. Improved reading of the maturity by adjusting the maturity reading resulted, however, in more reliable estimates of spawning stock size.

On the second day an invited lecture on the large program proposal called “The heritage of Nansen” (nansenlegacy.org) was presented by Paul Wassmann from the University of Tromsø. This program proposal focuses on a large scale research activity in the northern Barents Sea and Arctic Ocean to investigate the large scale oceanographic, biological and ice related ecosystem properties that also Nansen set out to investigate. Applications for funding of this program are sent to the Norwegian authorities and the Norwegian research council.

Conclusions to be drawn from this symposium are that there is a lot to do concerning uncertainty and variance in the stock assessments underlying the management of important fish stocks in the Barents Sea. However, harvest rules and other strategic work related to the assessment process indicate that the assessments are working adequate to set quotas for major fisheries.

In this volume, some papers are presented in full, others only by title and abstract. The former are those papers that are not planned for publication in a peer-reviewed journal, the latter are those that either have already been published elsewhere, or are planned to be submitted to other journals. In some cases a full paper was not submitted to the symposium.

December 2014

The editors

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Theme session I: Survey strategy and methodology

1.1 DeepVision: an in-trawl stereo camera makes a step forward in monitoring the pelagic community

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Ecosystem surveys are carried out annually in the Barents Sea by Russia and Norway to monitor the spatial distribution of ecosystem components and to study population dynamics. One component of the survey is mapping the upper pelagic zone using a trawl towed at several depths. However, the current technique with a single codend does not provide fine-scale spatial data needed to directly study species overlaps. An in-trawl camera system, Deep Vision, was mounted in front of the codend in order to acquire continuous images of all organisms passing. It was possible to identify and quantify of most young-of-the-year fish (e.g. *Gadus morhua*, *Boreogadus saida* and *Reinhardtius hippoglossoides*) and zooplankton, including Ctenophora, which are usually damaged in the codend. The system showed potential for measuring the length of small organisms and also recorded the vertical and horizontal positions where individuals were imaged. Young-of-the-year fish were difficult to identify when passing the camera at maximum range and to quantify during high densities. In addition, a large number of fish with damaged opercula were observed passing the Deep Vision camera during heaving; suggesting individuals had become entangled in meshes farther forward in the trawl. This indicates that unknown numbers of fish are probably lost in forward sections of the trawl and that the heaving procedure may influence the number of fish entering the codend, with implications for abundance indices and understanding population dynamics. This study suggests modifications to the Deep Vision and the trawl to increase our understanding of the population dynamics.

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PLOS ONE, DOI: 10.1371/journal.pone.0112304

<http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0112304>

1.2 Ecosystem approach to management: assessing the state of the Barents Sea ecosystem

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Ecosystem approach to management (EA) means integrated management of human activities across sectors, focusing on the state of the ecosystem. This is a dual focus, setting operational objectives to support the overall goal to maintain the functional integrity of the ecosystem on the one hand, and assessing the ever changing dynamic state of the ecosystem on the other. Integrated assessment is a core element of the EA and comprises compilation and evaluation of information on species and habitats, climatic and oceanographic forcing, trophic and other ecological interactions, and human activities and their impacts on the ecosystem including socioeconomic aspects. In integrated assessment can be seen as having three practical steps: i) collecting and preparing data; ii) analyzing the data including integrated analyses (e.g. multivariate analyses), and iii) interpreting the outcome from analyses by using the accumulated scientific knowledge.

We will perform and present the outcome of an integrated analysis of hydrographic, nutrients, plankton, 0-group fish, fish stocks, and possibly other data as a step towards an integrated assessment of the Barents Sea ecosystem.

1.3 The Barents Sea survey strategy: the way forward to monitor the ecosystem.

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Abstract

Russia and Norway has a long history of successful cooperation for monitoring and management of the Barents Sea marine resources. The Institute of Marine Research (IMR) and the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) have the primary responsibility for the Joint Norwegian-Russian monitoring of the living marine resources in the Barents Sea. During the last 30 years, the surveys have been expanded from the monitoring of single stocks, to also include a monitoring of the entire ecosystem. In this paper we focused on the main long-term surveys (a Norwegian-Russian winter survey, a Norwegian Lofoten survey, a Norwegian-Russian ecosystem survey (BESS) in autumn, and a Russian ground fish survey in late autumn) and found that these surveys (design, sampling, coverage, data flow), organising and funding were not optimal. The suggested comprehensive monitoring program seeks to establish a stable regulatory framework, securing that the monitoring program is carried out according to long-term plans (scientific, financial and organisational). Also, the monitoring program should secure long time-series of sufficient accuracy to separate large natural fluctuations in a dynamic ecosystem from changes caused by fisheries and other human impacts. Thus, there should be no need for annually to consider; 1) the time allocation for standard surveys by the national cruise planning committees, 2) new survey objectives and design, and 3) estimate the cost. The suggested monitoring program includes the standard ecosystem surveys focusing on specific objectives and processes, and for long-term monitoring of the system, a joint ecosystem survey in winter, a joint ecosystem survey in autumn, a joint bottom-trawl survey covering the continental slope in late autumn. This monitoring program will be augmented by a component of the international ecosystem survey for the Nordic Seas conducted in early summer. These standard surveys have been conducted for ten years or more, and increased effort is suggested in some seasons to cover the total area of occupancy for target species and important ecosystem processes. The cost of monitoring is a significant part of the budget for IMR and PINRO, and therefore, the suggested monitoring program seeks to eliminate most of disadvantages with present survey activities by standardisation and optimization of surveys, methods and data flow and also to improve cost efficiency. The long term plans should secure increased

competence and continuation of expertise for involved leaders, scientists, technicians and users.

Introduction

The monitoring of the living marine resources in the Barents Sea is a joint effort between Norway and Russia, and collaboration between the two countries has been ongoing since 1956. Traditional marine monitoring programs have generally focused collecting data for the commercial fish stocks and are used in stock assessments as a basis for producing fisheries management advice (recommended quotas etc.). Stock assessment in the narrow sense (analytical assessment) is a quantitative assessment of the size of a fish stock expressed as numbers and weight of fish in different age groups. Quotas are set for 1-2 years after the primary data were collected. This requires a projection where assumptions have to be made regarding population dynamics, including recruitment, growth and mortality. Stock assessment in a wider sense uses (or should use) information about other aspects in the ecosystem which influence a stock's development when projections are made and quotas are recommended. We know empirically that physical forcing (through changes in currents and water masses) has a strong influence on recruitment, distribution and dynamics of fish populations. Such information can therefore in principle help us make better interpretations based on valid assumptions and projections. In addition, the need to monitor important ecosystem processes, changes in habitats, biodiversity pollution level, climatic variability, etc has to be addressed.

The aim of this paper is to evaluate existing surveys and suggest a new comprehensive monitoring program. A future monitoring program should focus on monitoring the status of and changes in the Barents Sea Ecosystem and include the surveys conducted in different seasons, reflecting the main oceanographic and biological processes. An adequate temporal and spatial resolution and long-term standardized monitoring with sufficient sample sizes is important for detecting changes and monitor key processes and status of important ecosystem components. There is also a need to include and maintain existing time series in the monitoring program. This is important both to give input to stock assessment and to compare the level and variability of ecosystem components in the past, with the present and in the future to detect changes in the ecosystem.

Historic development and present situation

At IMR and PINRO experts groups have evaluated existing survey activities in the Barents Sea and suggested a monitoring strategy. A report from the project (no.14256 "Survey strategy for the Barents Sea") is edited by Elena Eriksen and Harald Gjøsæter, and the present paper builds upon that report, referred to as Eriksen and Gjøsæter (2013).

A short description of the Barents Sea ecosystem

Oceanographic conditions

The Barents Sea is a large shelf area (about 1.6 million km²) located at high latitudes between 70 and 80°N to the north of Norway and Russia. The bottom topography is complex with several large and small banks and deep trenches. The western part the Bear Island Trough provides a deep connection with the Norwegian Sea and in the northeast the St. Anna Trough provides a deep connection with the Arctic Ocean via the northern Kara Sea. The ocean currents are dominated by Atlantic Water flowing mainly from south west into and across the Barents Sea, however some inflow occurs from the West Spitsbergen Current to the northern Barents Sea through the deeper parts of the northern shelf (Loeng et al. 1997, Lind and Ingvaldsen 2012). Cold Arctic Water is found overlying the Atlantic Water in the northern Barents Sea. The inflowing Atlantic Water is relatively warm causing boreal conditions in the western and southern part of the Barents Sea, while the Arctic Water is cold and gives sub-arctic and arctic conditions in the northern part (Lind and Ingvaldsen 2012). Most of the sea ice in the Barents Sea is moving first-year pack ice which forms seasonally, and the extent of ice cover is highly variable depending on the climatic conditions. An area of about half the Barents Sea (around 0.7 million km²) can either be ice covered in cold years or remain open in warm years.

Primary and secondary production

The seasonal growth of phytoplankton is different in ice covered and ice free areas. In ice covered regions, the growth is highly influenced by ice melting causing vertical stability and thereby driving a short spring/summer phytoplankton bloom with low (about 50 g C m⁻²) primary production (Rey et al. 1987, Skjoldal et al. 1987). In contrast, the spring bloom in the Atlantic water mass is driven by seasonal warming and therefore slower and prolonged, but with considerably higher primary production (about 100 g C m⁻² per year (Skjoldal and Rey 1989). Thus in the Atlantic water mass there is a more effective coupling to the next level in the food web allowing more time for grazing zooplankton to exploit the phytoplankton production, while in the ice covered regions, due to the more short-lived ice edge blooms, there is more sedimentation of ungrazed production as energy input to deeper water and the benthos (Skjoldal and Rey 1989).

Fish

The majority of fish species in the Barents Sea are demersal species living at or associated with the bottom. In general, small demersal fish species feed largely on benthic invertebrates; larger demersal species feed more on small fish. There is also a large variation in diet composition over time and space, reflecting the dynamic changes in the Barents Sea ecosystem. The dominating pelagic planktivorous species (capelin, herring and polar cod) constitute an important link between lower and higher trophic levels in the Barents Sea ecosystem (Skjoldal and Rey 1989, Dolgov et al. 2011). The total biomass of fish in the Barents can be as high as 10-12 million tons. Capelin abundance in the ecosystem fluctuates, but when abundant it is by far the dominant pelagic species in terms

of biomass, while Atlantic cod is dominant among the demersal fish species (Johannesen et al. 2012).

All the major fish stocks in the Barents Sea have seasonal migrations within and for some, also outside the Barents Sea. The migrations give spatial closure to the life cycles in relation to the main current systems that transport larvae from spawning to nursery areas. The general pattern of migrations is south- and westward towards warmer water for wintering and ‘upstream’ for spawning in spring, and east- and northward for feeding in summer. The migrations may be dictated by the large-scale physical regime in terms of currents and water masses (for the purpose of spatial life cycle closure), but are also influenced by the migrations of other species, which constitute their prey (and possibly predators). For example, plankton-feeders, such as young herring, capelin and polar cod, have large-scale feeding migrations where they spread out and feed on the zooplankton then develop further in the upper water layer of subarctic and low-arctic waters during the short summer season.

The present survey activities

In this paper we give information about the surveys used for developing stock advice for the commercially important Barents Sea species. Several stocks are found both in the Norwegian Sea and the Barents Sea during their life-cycle (Table 1). In order to account for this spatial distribution, we have included here some surveys which also cover areas in the Norwegian Sea, such as the Lofoten survey (spawning cod), the Norwegian autumn ground gear survey of the continental slope (Greenland halibut) off northern Norway, and the international ecosystem survey in the Nordic Seas (herring, blue whiting). We have chosen to exclude the Norwegian coastal survey targeting saithe and coastal cod.

Norwegian-Russian (IMR-PINRO) winter survey (NRWS)

A combined acoustic and bottom trawl survey to obtain indices of abundance and estimates of length and weight at age for the major commercial ground fish stocks, has been carried out in the Barents Sea each winter (4-6 weeks in January- March) since 1981. Prior to 1993 a fixed standard area was covered, but in 1993 the survey area was extended to the north and east in order to obtain a more complete coverage of the younger age groups of cod (Table 2). The trawl gear was changed at the same time as when an inner net was added. This increased the catchability of small fish. The methodology (including changes over time) is described in Mehl et al. (2013). Since 2000 Russian vessels participated in the survey (except 2006-2007), and the total coverage was thus more complete, especially in 2008 and 2011 (Figure 1).

The winter survey is a combined acoustic and bottom trawl survey (see Jakobsen et al. 1997 for more details on trawl gear, protocol, and design). The survey area is divided into seven main areas (Figure 1) and 23 strata. The main outputs of the winter survey are stock assessments and quota advice, disseminated through the ICES system. Data from stock assessments as well as indices and data from the survey are used in management plans, reports and scientific publications.

During winter, the distribution of cod is less patchy and distributed over a smaller area than in summer and hence is more easily monitored. Timing is optimal also with respect to getting data on cod (and haddock) for estimating maturity ogives (combined with Lofoten survey). Maturity data are important for cod stock assessments. The amount of cod feeding on spawning capelin is an important determinant of the ultimate size of capelin spawning stock biomass.

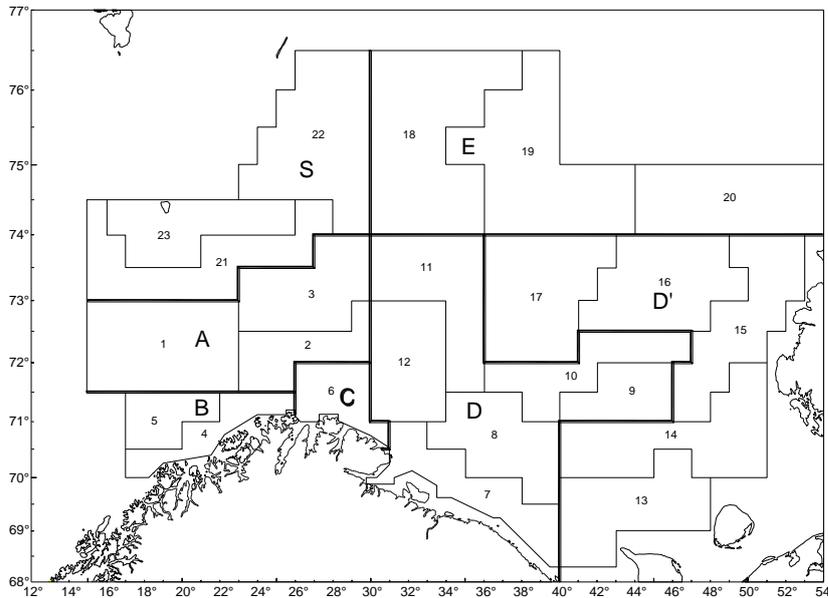


Figure 1.3.1. Strata (1-23) and main areas (A, B, C, D, D', E and S) used for swept area estimations. The main Areas are also used for acoustic estimation.

Norwegian spawning cod survey (NSCS)

The "skrei" survey is an acoustic survey carried out with one research vessel in the Lofoten and Vesterålen areas during the last half of March, and the aim of the survey is to map the abundance and distribution of the spawning cod stock (Figure 2).

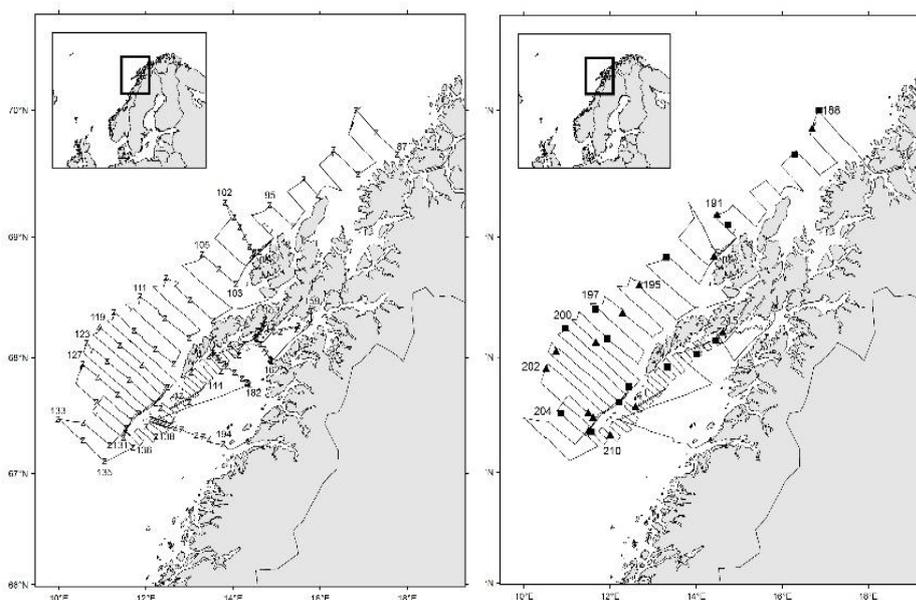


Figure 1.3.2. Survey map for NSCS survey 2013. CTD stations are shown at left, while trawl (pelagic and bottom) station are shown at right.

This survey is very informative for the stock assessments done by the ICES expert group AFWG, since the mature cod, which are poorly covered by the NRWS, is covered by this survey. We still miss some knowledge about the basic processes connected to the cod spawning in Lofoten, and for that reason, temperature and salinity are measured, egg samples are taken from net tows, and genetic analyses are carried out. The time series for this survey used in the assessments starts in 1985, but there were exploratory surveys in some prior years.

The summer international ecosystem survey for the Nordic Seas (IESNS)

This acoustic survey (see description in ICES 2012) is carried out in April-June, and survey coverage includes the southern part of the Barents Sea (Figure 3). The aim of the survey is to cover the entire spatial distribution of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock. In addition objective is to collect data on plankton and hydrographical conditions in the survey area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 the EU also participated (except 2002 and 2003), and from 2004 onwards, it was more integrated into an ecosystem survey. PINRO covers the Barents Sea (area I), while IMR and other countries cover areas II and III.

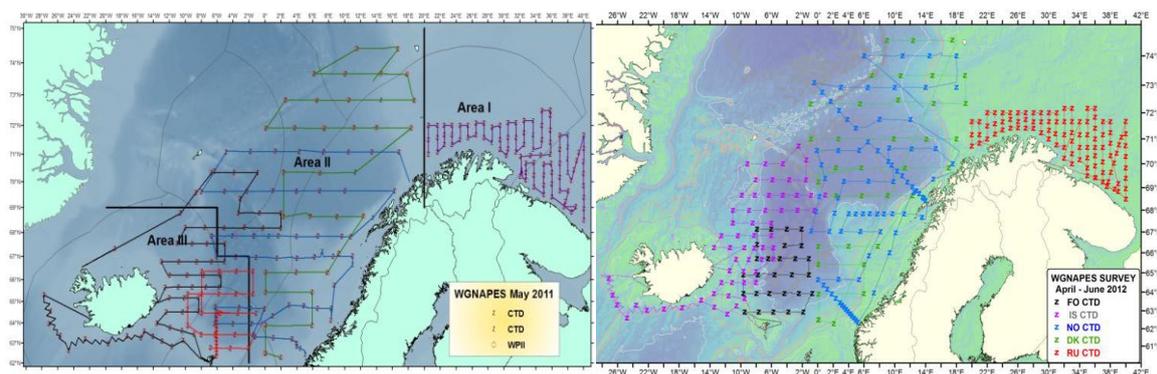


Figure 1.3.3. The International ecosystem survey in the Nordic Seas (April-June 2011 (left) and 2012 (right)) and area covered by CTD, WPII and trawl.

All vessels use a large or medium-sized pelagic trawl as the main tool for biological sampling. The target species are herring and blue whiting. The hydrographical and plankton stations are shown in Figure 3.

Joint Norwegian-Russian Ecosystem survey in the Barents Sea during autumn (BESS)

The autumn ecosystem survey of the Barents Sea (BESS) emerged from a conglomerate of surveys previously carried out, and some additional investigations were added to study various aspects of the ecosystem (Table 2).

The entire Barents Sea is usually ice-free in autumn, and hence the total distribution area of all Barents Sea stocks, except from those associated with ice, can be covered. This is a period when organisms have minimal migration due to feeding. Also, near the end of the feeding period, it is possible to assess the outcome of the annual production of living resources by measuring the gain in length and weight by fish in the various stocks during

the year. This period is ideal for: 1) assessing the capelin stock with the purpose of giving quota advice for the winter fishery due the maturing part of the stock, which forms the basis for the quota advice, can be assessed; 2) determining when the 0-group of commercially and ecologically important fish is abundant.

The survey design of BESS-autumn consists of a uniform sampling intensity in the general survey (Figure 4). Stations with fixed location within a regular grid are called “ecosystem stations”. An ecosystem station is a cluster of local stations of various types. Normally an ecosystem station includes a CTD-profile, two hauls with WP2, a pelagic and a bottom trawl haul. The methodology is described in Michalsen et al. 2011.

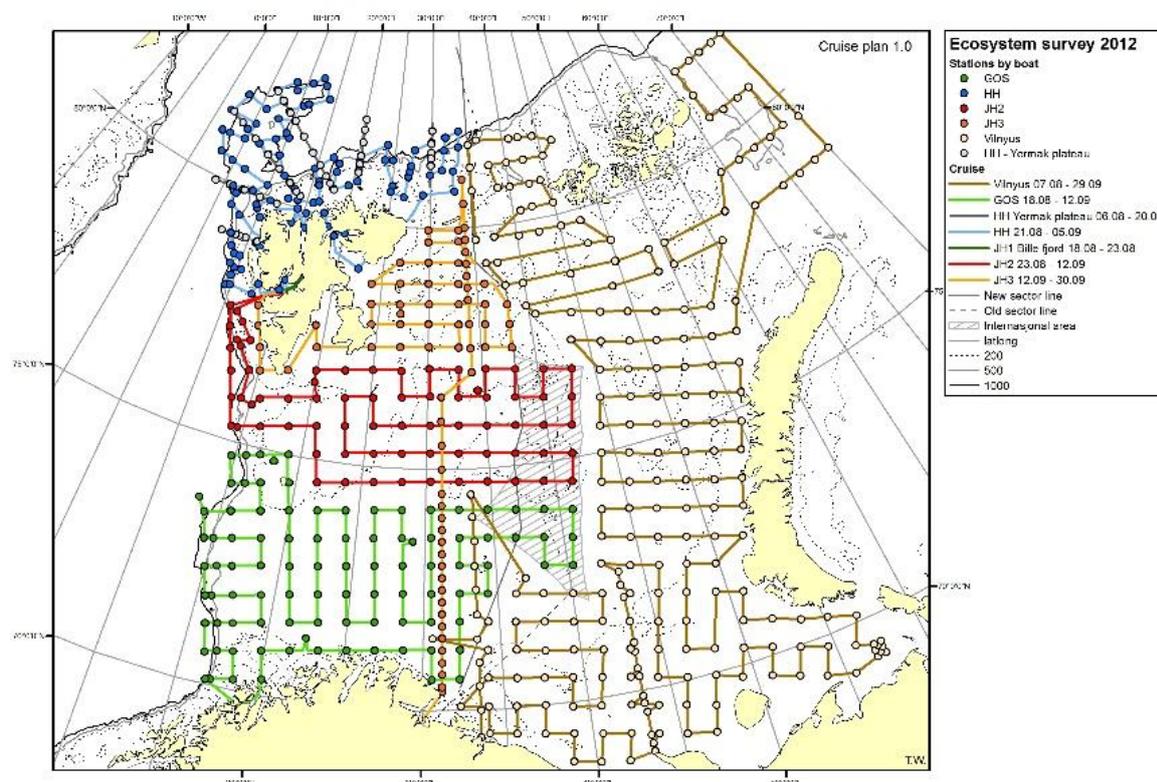


Figure 1.3.4. Map of the survey area BESS-autumn survey in 2012.

Data from BESS, are used in stock assessments to generate abundance indices which, other data, are used in management plans, reports and scientific publications. Results are also widely used in internal and external projects.

Norwegian autumn ground gear survey at the continental slope (NGGS)

Since 1994 a depth stratified survey has been conducted yearly along the continental slope in the Norwegian/Barents Sea (68-80°N, 400-1500 m) using factory trawlers. The main focus since the start of this survey has been to describe the adult part of the Greenland halibut (*Reinhardtius hippoglossoides*) stock in this area (Figure 1.3.5). From 2009 an

improved sampling regime concerning the by-catch species was initiated, resulting in a more appropriate description of these species with regard to distribution and abundance.

In 2011 a long-term survey strategy for Norwegian deep-sea fish surveys was developed by the IMR, and the methodology (including changes over time) is described in Harbitz (2011).

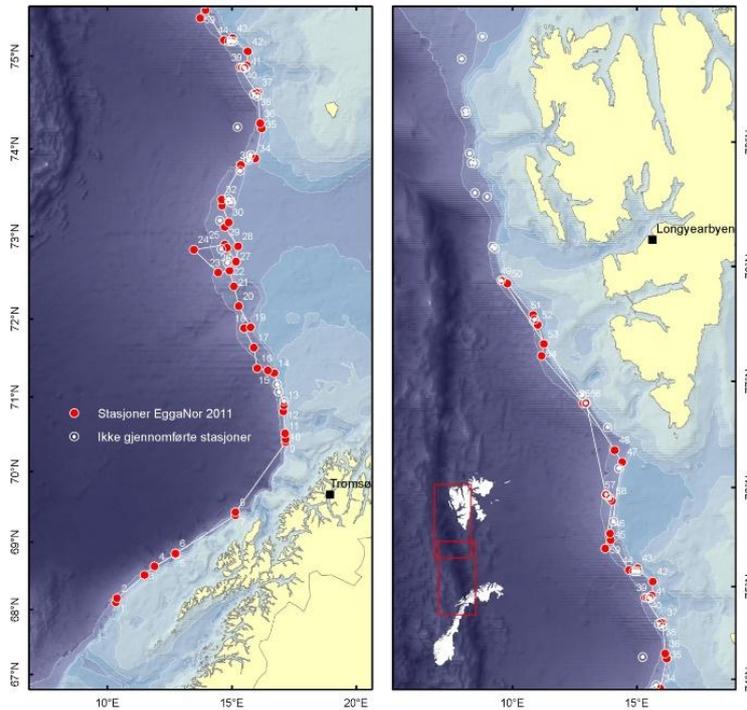


Figure 1.3.5. Map of the survey area, showing realized (red dots) and planned (white dots) trawl stations.

Russian late autumn-winter survey (RAWS)

Surveys for cod and haddock juveniles have been conducted by PINRO since 1946, up to 1981 during two periods, September-October and November-December. In 1982, the investigations were transferred to the Russian Autumn-Winter multispecies trawl-acoustic survey (MS TAS) for assessment of juveniles and estimation of the main commercial Barents Sea stocks indices (Lepesevich and Shevelev, 1997), which have now been limited to October-December. The survey was conducted by two-three vessels, for approximately 150 days at sea between the end of 1980s and mid-1990s, while vessel participations as well as duration was reduced to two vessels for 90-100 days due to decreased funding.

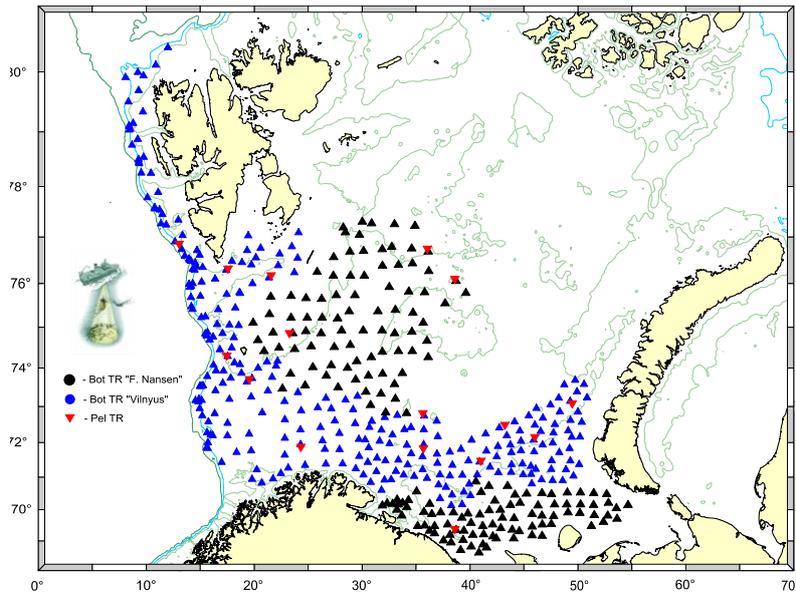


Figure 1.3.6. RAWS Survey map in 2001.

During late autumn-winter cod are less patchy and distributed over a smaller area than in summer. Timing is optimal also with respect to getting data on cod (and haddock) maturity ogives. Survey could cover almost the entire stock in late autumn, since cod has not yet started their spawning migration. There may be some ice problems, but less than during Norwegian winter survey.

Survey design is variable. The route of each survey, periods and number of stations are selected depending on the targeted commercial species distribution, which is known from previous surveys. The design of the survey tries to cover the stock up to the zero distribution line in the shortest possible time, to avoid problems with migration.

Trawling on echo registrations are carried out when necessary using the Russian bottom trawl (number 2283-02 with mesh size 16 mm in the cod end, and an attached net for sampling of krill) which can be operated down to 1200 m. This trawl used during the RAWS is less appropriate for 0-2 year old cod and haddock compared with the Campelen trawl used during the NRWS and BESS.

The results concerning cod, haddock and Greenland halibut from the survey are input data for the analytical assessment models (VPA) used by the Arctic fisheries working group in ICES. The survey results are also reported in various internal and external reports and scientific publications.

Disadvantages of the present monitoring activities:

- lack of a long-term perspective gives few opportunities to consider complementary sampling between surveys/seasons
- poor definition and prioritization of objectives result in difficulties in effort allocation between different tasks during the planning of the various surveys

- lack of coordination of late autumn/winter survey activity: 4 surveys cover partly the same area, incomplete coverage of target species distribution
- lack of communication and coordination of survey planning results in sub-optimal survey activity
- reduction of resources (time and money) corresponding with increase demand for covering more ecosystem components, processes, and area results in mismatch between objectives and resources
- lack of an integrated data framework results no coupling between different data bases and surveys

Suggestions for future monitoring

The suggested monitoring program seeks to establish a stable regulatory framework, securing that the monitoring program is carried out according to long-term plans (scientific, financial and organisational). Thus, there should be no need for annually to consider: 1) the time allocation for standard surveys by the national cruise planning committees; 2) new survey objectives and design, and; 3) estimating the cost of the survey. The long term plans should secure increased competence and continuation of expertise for the involved leaders, scientists, technicians and users.

Description of which species, areas, processes, etc. that should be monitored and when

Oceanographic processes

The aim of the oceanographic investigations is to obtain estimates of the horizontal and vertical distribution of water temperature, salinity and nutrients in the Barents Sea. The Atlantic inflow in the southwest has a profound impact on the Barents Sea temperatures and should get special attention. Depth profiles over the total survey area and along the standard oceanographic sections (Fugløya-Bear Island, Vardø-North, Bear Island-West, North Cape–Bear Island, Kola and Kanin) should be made, as well as sampling of spatial data (temperature, salinity, and nutrients) at each trawl station.

Ecologically important species and groups

More than 200 species of fish have been recorded in the Barents Sea. There are also thousands of benthic invertebrate species and a diverse plankton community, seabirds and many species of marine mammals that inhabit or visit the area (Stiansen et al., 2009).

Common zooplankton organisms in the Barents Sea are copepods, amphipods and euphausiids, jellyfish, pelagic gastropods, arrow worms, larvae of crabs, and eggs and larvae of fish. Among the zooplankton, copepods are the most important group in terms of biomass and abundance, followed by euphausiids. These three zooplankton groups constitute a large part of the diet of several fish species and marine mammals and birds. The most important plankton species and optimal coverage are given in Table 3.

The Barents Sea contains several large stocks of fish that are key species in the Barents Sea food web. From an ecological perspective the monitoring effort should be prioritized according to the following criteria: 1) ecological dominance - typically includes the abundant commercial species; 2) sensitivity, typically long lived species with low fecundity, or that are restricted to species habitat (this will be red listed species) and; 3) species that are important representatives for bio-geographic groups. The most important fish species according to these criteria and optimal coverage periods for each of them are given in Table 3.

More than 300 invertebrate taxa have been recorded during the ecosystem surveys from year 2006 to 2012. The composition of the benthic fauna is strongly influenced by bottom

topography and water masses, and there is a strong biogeographical gradient across the sampling area. Barents Sea invertebrate and benthos investigations are still in the descriptive phase, and therefore the number of individuals and total weight of each benthos taxon is important information. The most important benthos species are given in Table 3.

About 25 species of marine mammals regularly occur in the Barents Sea, comprising 7 pinnipeds (seals and walrus), 12 large cetaceans (large whales), 5 small cetaceans (porpoises and dolphins) and polar bears (*Ursus maritimus*) (Table 3).

Trophic interaction

Coordinated studies between PINRO and IMR on the diet of cod, capelin and polar cod in the Barents Sea were conducted in 1984, 2005 and 2007, and the main aims of these investigations were to identify the key feeding areas and their main prey, climate impact on food and feeding conditions, and interactions with prey (Eriksen and Gjørseter, 2013).

Suggested survey program

Standard surveys, conducted in different seasons, and adequate sampling effort and spatial coverage are needed to be able to detect changes and monitor key processes and the status of the ecosystem (Table 4). Standard surveys, are surveys that are conducted at a predetermined; time of year, duration, location, sampling procedures, with sufficient funding to conduct the survey. Each standard survey should be designed differently with regards to primary, secondary and additional objectives, optimal seasonal/temporal and spatial coverage. The standard survey should also be seen as a scientific platform for developing and improving new methodology, technology and a platform for conducting additional investigations. Such work calls for additional financing. The detailed information of standard surveys, including timing, duration, location, sampling, competence and cost and in addition some suggestions for further development of observation and estimation methods needed for optimising surveys effort are given in Eriksen and Gjørseter (ed) 2013. The monitoring program should include the following standard surveys and time frames:

- A joint ecosystem survey of at least 150 vessel days in winter, to be carried out over a period of maximum 6 weeks length
- A joint ecosystem survey of at least 160 vessel days in autumn, to be carried out in a period of maximum 6 weeks
- A joint ground gear survey covering the continental slope of at least 25 days in late autumn
- The segment of the summer international ecosystem survey for the Nordic Seas covering the Barents Sea in early summer

Thus, there should be no need for annually to consider; 1) the time allocation for standard surveys by the national cruise planning committees, 2) new survey objectives and design, and 3) estimate the cost.

However, for the winter survey, studies are still ongoing regarding how the present four surveys during autumn-winter could be combined into two joint surveys, with regards to; 1) propose a possible optimal design and timing of surveys, 2) analyse possible consequences of changes in monitoring procedures for the bottom fish stocks on their assessments and, 3) propose a transition plan for current surveys to new survey(s) if it will be deemed necessary.

The existing Joint Norwegian-Russian Ecosystem survey during winter (BESS-winter) is appropriate for monitoring spawning migration of key Barents Sea fish species and oceanographic shifts and may ensure updated information of the commercial and ecologically important bottom fish stocks for assessment and fisheries management advice (Table 4). This survey may also give information about the spawning migration of capelin, the pelagic components of commercially important fish species, and temperature conditions.

To achieve this, the survey should cover the annual distribution of the total stocks of cod and haddock and the winter distribution of redfishes, Greenland halibut and mature capelin. Additionally, it should include a sufficiently dense grid of stations per stratum in all areas and include sufficiently frequent biological sampling (fish length and weight, gonad weight, maturity and age) in order to make an abundance estimation that has an acceptable level of uncertainty. It should also include pelagic trawling on echo registrations as well as pelagic trawling at pre-determined positions, and the ability to produce maps of oceanographic conditions by collecting oceanographic data (temperature and salinity) from all pelagic stations (Eriksen and Gjørseter, 2013). While some of the recommendations are definite, studies are still ongoing regarding how the present four surveys during autumn-winter could be combined into two joint surveys.

The existing joint ecosystem survey in spring/early summer in the Nordic Sea covers the southern and western parts of the Barents Sea, and consequently we recommend that rather than establishing a new summer survey in the Barents Sea, one should seek cooperation within the existing survey, and use data from the Barents Sea's part of the survey. An analysis of the data collected by this survey may show if survey time and methods are optimal, and could help in concluding whether this survey (possibly modified and expanded) could fulfil the needs for monitoring during summer or determine whether a completely new survey for the Barents Sea should be designed.

The Joint Norwegian-Russian Ecosystem survey in the Barents Sea during autumn (BESS-autumn) is appropriate for assessing the success of the feeding season, and the surveys are able to monitor the whole ecosystem since the largest ice-free area is found during this period. Normally the feeding pelagic stocks have minimal migrations during this period, which makes it ideal for assessing the commercial and ecologically important pelagic fish stocks (capelin, polar cod, herring and blue whiting) and for giving advice on the shrimp stocks.. Since the 0-group of most fish species are found in the upper layers during this period, this survey is also a suitable vehicle for monitoring the annual recruitment for most

fish stocks. Due to the large covered area, this survey is also suitable for providing updated information on other commercially and ecologically important species, and for other ecosystem components (plankton, benthos, marine mammals and sea birds, together with environmental condition (temperature, salinity, oxygen and pollution), biodiversity and trophic interaction.

During BESS-autumn a huge number of samples are collected and processed and therefore we recommend reduction of sample sizes for 0-group and non-commercially fish species from 100 to 30 (Pennington and Helle, this volume). We recommend reducing number of stations with extended fish sampling in the “Arctic area” and limit this only to ecosystem-stations. We also recommend efficiency for plankton sampling by reducing the frequency of WP-II hauls from 300 to 100 while increasing MOCNESS/Multinet or similar equipment (Eriksen et al. this volume), which would obtain a vertical resolution of plankton data, this makes it easier to scrutinize acoustic readings during the survey and gives useful data for ecological studies. The monitoring of capelin stocks needs more survey effort, especially in areas with denser fish concentrations (south, east and north east of Svalbard) and regular sampling by acoustic fish registrations (Tjelmeland et al., this volume).

A joint ground fish survey in late autumn is optional, but this point has not yet been thoroughly discussed among experts from the IMR and PINRO. An optimal allocation of survey time to cover the ground fish stocks during autumn/winter/early spring is an ongoing discussion.. If possible, a solution combining the present Russian late autumn survey, the joint survey in February, and the Norwegian Lofoten survey in March should be sought for.

Detailed recommendations for the monitoring program

A sufficient number of days at sea is crucial to cover a specific area, therefore a decline in ship time will negatively influence the temporal and geographical coverage, station frequency, number of sampling devices employed per station, processing of the samples and consequently the amount and quality of data collected will suffer. Therefore, we estimated the ship time needed for different surveys with a standard sampling program, while securing some flexibility with regards to changes in the distribution of target species.

Organising and funding

Organising and conducting surveys is a tremendous effort: the planning, carrying out, data processing and reporting survey results has been organized and financed in various ways. It was established, that the organizing, funding, and planning of some of the surveys have not been optimal. First of all, the funding has been cut from year to year, without a thorough analysis of the consequences. Also, the fact that the survey budgets have been split into several projects has made the planning of the surveys difficult and the allocations of cost difficult to monitor.

We recommend that each survey is organized at each institution as one project, lead by a scientific coordinator who leads a team that includes scientific and technical expertise. In addition, a committee should coordinate the total monitoring activity in the Barents Sea, as well as the development and implementation of new methods and equipment. At the IMR, this committee should be lead by the program leader, directing a team that includes the scientific coordinators for the various surveys. We do not recommend any specific organisation of the cruise activity at PINRO, but a similar organisation as that described here should be considered.

To obtain continuous evaluation and development of these surveys, an ICES WGIBAR should be established, similarly to the existing WGIPS. This multidisciplinary working group, which at the start, should be lead by two co-chairs (IMR and PINRO), may identify knowledge gaps, weaknesses with monitoring (survey design, sampling, estimations methods, data flow and products) and recommend changes to the monitoring committees mentioned above. This working group should focus on analysing data from all monitoring surveys to obtain an annual status report for the Barents Sea, summarizing information from these surveys.

Three levels of organisation; cruise planning teams, a coordinating committee, and a multidisciplinary working group with close communication between them, may secure optimal sampling schemes among surveys/seasons, and may increase the focus on the development and improvement of survey methodology, and multidisciplinary data use. Such organization may also increase competence of people involved as well as users of survey data.

Competence

Diverse investigations during surveys call for manning by technicians/scientists with varied expertise. It is vital that the institutes have enough of the right expertise to take care of all kinds of sampling, and the manning of individual surveys must be adapted to the tasks. If expertise is lacking, the committees should rectify this need by employing new experts or upgrading the staff. Joint IMR-PINRO workshops should secure a continuity of sample processing and comparable results.

Survey equipment

To cover most aspects of the ecosystem, a range of methods and gears are applied; water sampling using a CTD with a sampling rosette, plankton nets, pelagic and demersal trawls, grabs and sledges, echo sounders and direct visual observations. In some cases, different equipment is used by IMR and PINRO. Standardization of equipments and methods is vital for proper monitoring, and therefore we recommend that a set of survey manuals are prepared, updated and strictly followed during the planning and carrying out of the surveys. All equipment should be standardized and calibrated. The institutes should clarify who are responsible persons/groups for this standardization of equipment.

In addition to standardization, time and money should be set aside for testing new equipment and methods for future implementation in the monitoring surveys. To reach this need, a well-defined strategic program (IMR and PINRO) aimed to develop and implement new observation methods and equipments, which are able to monitor continuously the vertical distribution of the most important organisms and environmental parameters should be established.

Huge amounts of data are collected during these monitoring surveys. Most data will complement existing time series, while some data belong to special investigations conducted once or to projects of short duration. A standardization of data products emerging from the surveys should be done. A framework, including all aspects of data flow from measurements to safe storage in databases, quality assurance and easy retrieval of data for use in estimation programs, etc., is highly needed. The ongoing work in the project Sea2Data is important in this respect, and further development of this data framework, in cooperation with PINRO, is recommended.

To cover most aspects of the ecosystem, a range of methods are applied, from plankton sampling to sea mammal's visual observation. Sampling methodology and estimation of different parameters should be strengthened to improve survey efficiency and effectiveness. We propose that 10% of the survey time be allocated to experimental studies to check whether current sampling methods are optimal, or if sampling design, sampling and subsampling organisms, environmental parameters, etc. should be changed. Further, various methods for estimation of stock parameters should be investigated, to decide on standard methods for the future. The multidisciplinary team should make priorities for such investigations.

Additionally, the suggested long-term perspective of the monitoring programs gives opportunities: a 'data rich' scientific platform has the potential to address current/future ecosystem questions; gives more flexibility in resource allocation (e.g. ship time, expertise and funding); may enhance the development of new data systems, may facilitate integrated analyses, and can encourage the development and improvement of methodology and technology due to efficiency requirements for simultaneous monitoring.

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Tables

Table 1. General information and abbreviation for various surveys.

Surveys	Time	Coverage area	Abbreviation
Norwegian-Russian winter survey	February-March	Central, west, east, south	NRWS
Norwegian spawning cod survey	March-April	Lofoten (Norwegian coast)	NSCS
Joint Norwegian-Russian Ecosystem survey in the Barents Sea during autumn	August-September	Whole Barents Sea	BESS
The international ecosystem survey in the Nordic Seas	May-June	South-western part	IESNS
Norwegian autumn ground gear survey	November	The continental slope	NGGS
Russian late autumn-winter survey	November-December	The continental slope, Central, west, east, south	RAWS

Table 2. Time series of investigations and their start (stop) date included in present surveys. To be included in the table, the investigation must have been carried out annually with consistent area coverage and survey methods.

Investigation	Methods	Start/ stop
<i>Norwegian-Russian (IMR-PINRO) winter survey (NRWS, February-March)</i>		
Cod	combined acoustic and bottom trawl	1981
Haddock	combined acoustic and bottom trawl	1981
Redfish species	bottom trawl	1986
Shrimp	bottom trawl	1981/ 2009
Greenland halibut	bottom trawl	1989
Capelin spawning migration	combined trawl and acoustics	2011
Blue whiting	bottom trawl	2001
<i>Joint Norwegian-Russian Ecosystem survey in the Barents Sea during autumn (BEES, August-September)</i>		
Hydrographic survey	CTD, water samplers	1965
0-group	Pelagic trawl	1965
		standardized methods since 1980
Shrimp	Demersal trawl	1981
Acoustic survey	Combined trawl and acoustics	1972 – capelin 1985 – young herring 1986 – polar cod 2004 – blue whiting 2003 – cod 2003 – haddock
Plankton	WP2, Mocness	1989
Bottom trawl survey	Demersal trawl	2004 – cod, haddock, Greenland halibut, wolffishes, redfishes, long rough dab, non-commercial fish (Spitsbergen area covered since 1981)
Benthos by-catch	Demersal trawl	2005
Marine mammals and birds	Observations	2003 (Norwegian boats)
Garbage	Surface observations	2010
	Pelagic trawl	
	Demersal trawl	
Pollution	CTD, grabs	2003
<i>Russian late autumn-winter survey (RAWS)</i>		
Cod	combined acoustic and bottom trawl	1982, standardized methods since 1986
Haddock	combined acoustic and bottom trawl	1982, standardized methods since 1986
Greenland halibut	bottom trawl	1992/
Redfish species	combined acoustic and bottom trawl	1992/
Capelin, polar cod, herring, blue whiting	combined trawl and acoustics	1986/
Wolffishes, long rough dab, non-commercial fish	bottom trawl	1982/
Secondary objectives: most arctic species due to slow growth and low fecundity (lumpsucker, skate, Lycodes, shark, shrimps)	bottom trawl	1990/
Additional objectives: oceanography	CTD	1979/
Additional objectives: plankton	Juday nets	1990/

Table 3. The most important species, variable measures, optimal timing, survey, applications. 1-BESS-Winter, 2-IESNS, 3-BESS- Autumn and 4-JGGS.

Component monitored		Variable measured	Application	Surveys
Currents		Current vectors	Current fields, model input	Optimal:1,3; suboptimal:3
Water masses		Temperature, Salinity, Depth, Oxygen, Fluorescence, Light	Distribution of water masses, input to models	Optimal:1,2,3; suboptimal:13
Nutrients		Nutrient levels	Mapping of nutrient levels	Optimal: 2,3; suboptimal: -3
Pollution		Pollution levels	Mapping of pollution levels in the BS. Advice to Ministry of Environment/Fisheries	Optimal: 3
Phytoplankton		Species composition and abundance, chlorophyll <i>a</i> , fluorescence,	Mapping of distribution, research, input to management plan	Optimal: 2,3; suboptimal: -3
Zooplankton	Metridia lucens M. longa Calanus glacialis C.hyperborus C. finmarchicus Pareuchaeta norvegica P.glacialis P. spp. Onisimus nansenii O.glacialis Gammarus wilkitzkii Themisto abyssorum T. libellula T. compressa Meganyctiphanes norvegica Thysanoessa inermis T. longicaudata T. raschii L. helicina L. retroversa Cyanea capillata, krill ssp	Biomass, species composition and abundance Biomass, species composition	Mapping of distribution and biomasses, input to management plan, internal and external reports	Optimal: 2,3; suboptimal: 3

Table 3 cont.

Target fish/invertebrate species				
Bottom fish	Cod, Haddock, Greenland halibut, Redfish	Numbers, biomass, length, sex, maturity status, diet composition. Vertical distribution, SA, TS	Mapping of distribution, Assessment –ICES advice, internal reports, input to management plan	Optimal: 1,3,4; suboptimal: -1,4
Pelagic fish	Capelin, Herring, Blue whiting, Polar cod	Numbers, biomass, length, sex, maturity status Numbers, biomass, length, sex, maturity status Vertical distribution, SA, TS	Mapping of distribution, Assessment –ICES advice, input to management plan, internal and external reports	Optimal: 1,2,3; suboptimal: -2,3
0-group fish	Capelin, herring, cod, haddock, saithe, redfish, Greenland halibut, long rough dab, and of polar cod	Numbers, length Vertical distribution, SA, TS	Mapping of distribution, Assessment –ICES advice, input to management plan, internal and external reports	Optimal: 3
Invertebrate	Northern shrimps, King crab and snow crab	Numbers, biomass, length, sex, maturity status	Mapping of distribution, Assessment –ICES advice, input to management plan internal and external reports	Optimal: 1,3; suboptimal: -3
Other fish species monitored	Agonidae, Ammodytidae, Cottidae, Liparidae, Myctophidae and Stichaeidae and other fish	Numbers, length, biomass (group)	Mapping of distribution, internal and external reports	Optimal: 1,3,4; suboptimal: -3
Benthos communities	Ophiuroidea, Gorgonacephalus arcticus, Geodia sp, Actiniaria, Porifera, <i>Hyas</i> sp, <i>Sabinea septemcarinata</i> , Strongylocentrotus sp, Ophiopleura borealis (Ophiacantha bidentata, <i>S. septemcarinata</i>) Metridium senile (Brisaster fragile, Ophiacantha bidentata), Actiniaria	Numbers, biomass (species/group)	Mapping of distribution, internal and external reports, input to management plan	Optimal: 1,3; suboptimal: 3
Marine mammals	harp seals, white - beaked dolphins, killer whales, sperm whale, humpback whales, minke whales, fin whales other toothed whales	numbers	Ecosystem status reports (ICES, and joint IMR/PINRO), input to management plan	Optimal: 2,3; suboptimal: -3

Table 4. Existing survey activity and suggested monitoring program. Short description of various surveys.

Existing monitoring	Suggested monitoring	Primary objectives	Secondary objectives	Additional objectives
NRWS (90 days) NSCS (20 days) RAWS (30days)	BESS- winter 150 days: NO-80, RU-70	Demersal fishes: cod, haddock, Greenland halibut, redfishes	Pelagic fishes: capelin, herring, blue whiting Interspecies interaction Young groups of other commercial species	young Oceanography
Data not used	IESNS summer	Pelagic fishes: young herring, blue whiting	Plankton	Oceanography
BESS-autumn (160 days)	BESS-autumn 160 days: NO-90, RU-70	Pelagic fishes: capelin, young herring, blue whiting Shrimps	Young groups of other commercial species Demersal fishes: cod, haddock, Greenland halibut, redfishes, wolffishes Interspecies interaction Pollution	Oceanography Plankton Fish biodiversity Bentos Marine mammals Sea birds
NGGS (20days) RAWS	JGGS late autumn, at least 25 days	Demersal fishes: Greenland halibut, redfishes	fish community	

1.4 The methodological challenges to evaluation of euphausiids stocks and their role in the Barents Sea ecosystem.

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Euphausiids play a significant role in the Barents Sea ecosystem, providing energy transport between different trophic levels. The current paper presents the results of a long-term study based on pelagic trawl catches during feeding season (August-September 1980-2011 – total biomass) and bottom catches (October-December 1980-2011 – total abundance and biomass, species and age composition) during formation pre-wintering concentrations. Euphausiids data have been sampled annually by IMR (Norway) and PINRO (Russia). In addition, data on total abundance and biomass as well as stage composition of euphausiids juveniles during cold and warm years on the Kola section were used to characterize a level of euphausiids drift into the Barents Sea. Spatial and temporal distribution of euphausiids, based on two surveys, is compared and discussed. The krill stock's biomass estimation based on autumn and winter data will be compared and analyzed using data on euphausiid consumption by the most abundant predators (capelin, cod, 0-group and other fish). This paper discusses the methodological challenges in euphausiids sampling and possible improvements of the methodology: spatial and temporal coverage, seasonal sampling and consumption calculations.

1.5 Significance of cod settlement on 0-group cod abundance indices

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Abstract

0-group investigations in the Barents Sea have been carried out since 1965 and aimed to get the first indication of the year class strength for several commercially important fish species, including cod. Since 1980, the standard trawling procedures were used on all Russians and Norwegians vessels. The 0-group abundance indices based on stratified sample mean method, and are utilized indirectly in the fish stock assessment, recruitment studies and ecosystem modeling. However, the estimation of settlement of 0-group cod during survey has not been established. Since 2004 there has been conducted simultaneously pelagic and the demersal observations, and these showed that the cod may start settlement in August - September and that process varied between years and areas. However, this component consist only 0.2 -1.1% of total numbers, with 0.5% on average, and therefore too small to influence significantly abundance indices. Suggestions for improvement of survey (the spatial and temporal coverage) and estimation methodology are made.

Introduction

The knowledge of the size of the recruiting year classes is an important contribution for a successful assessment. The main goal with the Joint International 0-group fish survey has been to give an initial indication of year class strength of the commercially important fish stocks in the Barents Sea. The survey has been conducted since 1965 by the Institute of Marine Research, (IMR), Norway, the Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia, and the United Kingdom (up until 1976). Since 2004 the 0-group survey has been a part of a Joint Norwegian-Russian ecosystem survey of the Barents Sea.

Developing methods for estimating year class strength/abundance has been an urgent task during the whole investigation period. The possibility of estimating abundance of 0-group fish, using echo-sounder was presented by Dragesund and Olsen (1965). Haug & Nakken (1973, 1977) developed the area index method. The “logarithmic index” method, developed by Randa (1984), was used until 2004. Dingsør (2005) applied the “stratified sample mean” method and calculated the 0-group indices, this procedure was further developed (Eriksen *et al.* 2009) and is now the standard method for establishing the 0-group indices in the Barents Sea.

Northeast Arctic cod (*Gadus morhua*) is commercially and ecologically important fish species in the Barents Sea. There is little information in the literature about when cod change from pelagic life-stage to a demersal life-stage in the Barents Sea. Several studies from other areas indicated no clear relationship between fish age (in days) and fish length (in mm) and in addition fish of similar length settle at different times (Hussy et al. 2003; Anon. 2009). Boitsov et al. (1996) stated that the transition (settlement) is a rather prolonged process occurring in September-October in the Spitsbergen area and October-November in the Southern Barents Sea. The settlement of cod and their food items occurs gradually and it is likely to be connected with a convection mixing of water layers and descending of the thermocline layer (Ozhigin et al. 1999). It is assumed that for cod the transition occurs gradually during the autumn (Anon. 2006, 2009). The proportion of fish which already have settled at survey time have not been estimated, however ignoring this process means that estimates may probably be underestimates.

The aim of this paper is to estimate part of cod 0-group, which settle to the bottom during the Ecosystem survey and indicate how that influence precision of abundance indices. Additionally, propose suggestions for improvement of survey (the spatial and temporal coverage) and estimation methodology are made.

Materials and methods

The autumn ecosystem survey of the Barents Sea (BESS, 2004-) emerged from a conglomerate of surveys (among these were the 0-group survey) previously carried out to study various aspects of the ecosystem and providing data for fish stock assessment, time series (among these of 0-group abundance indices). The survey design of BESS consists of a uniform sampling intensity in the general survey. A regular grid with fixed positions of stations from year to year makes it possible to measure changed in spatial distributions, and it is suitable for covering a large spatial area, with many different processes (Figure 1). Stations with fixed location within a regular grid are called “ecosystem stations”. An ecosystem station is a cluster of local stations of various types, normally an ecosystem station includes a CTD-profile, two hauls with WP2, a pelagic and a bottom trawl hauls.

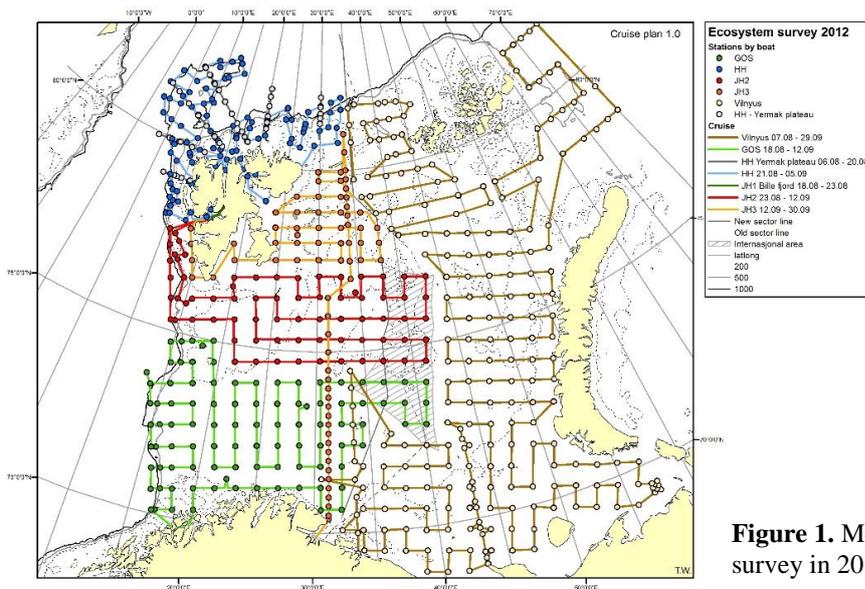


Figure 1. Map of the survey area BESS survey in 2012.

We used 0-group cod data from pelagic and bottom catches, taken at ecosystem stations for the period 2004-2012. Fish catches standardised for towed distance and annual abundance calculated by standard methods described by Jakobsen et al. (1997), Dingsør (2005), Eriksen et al. (2009). The detailed information about trawling procedure and calculation methods is available in Eriksen (Ed) 2012. We assumed that the cod settlement started if demersal catches were much higher than pelagic catches.

Results and discussion

0-group cod abundance indices varied between years and the overall trend was an increase until 2011, the year of record high year class of cod. 0-group cod abundance indices, taken by pelagic trawl, varied from 25 to 450 billion during the period 2004-2012. Numbers of cod taken by demersal trawl varied between 120 and 900 million, representing only 0.2-1.1 % of pelagic indices (Figure 2). This settled part of cod is, therefore, too small to influence 0-group abundance indices considerably, and can be ignored in abundance estimates.

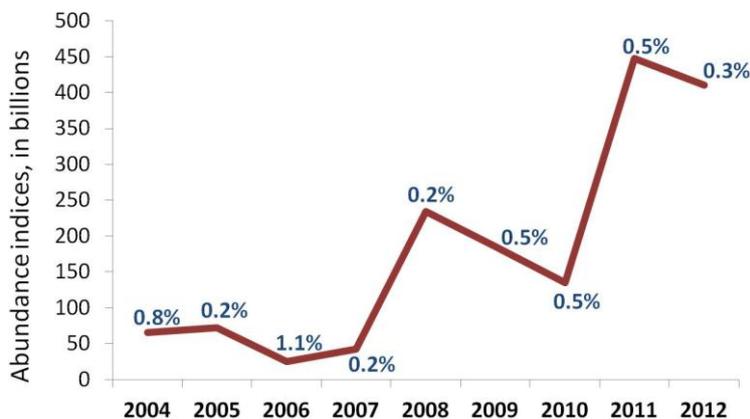


Figure 2. 0-grpup cod abundance indices based on pelagic trawl catches (red lines) and the part of 0-group cod (percentage) taken by bottom trawl of total numbers taken by pelagic trawls.

The majority of cod, distributing in the core area, was registered by pelagic trawl during BESS (Figure 3 and 4). The highest catches were observed in the central area, and taken by pelagic trawl. The demersal catches, taken during the whole survey, were low, and therefore, diminutive to influence 0-group abundance indices considerably, and can be ignored in abundance estimates.

Figure 4 shown spatial distributions of 0-group cod, taken by different gears. The higher bottom catches, indicating most likely cod settlement, shows varied settlement pattern between years and areas. The overall low cod numbers of settled cod were observed during 2005-2007, years of record warm temperatures in the Barents Sea and a relative stable low 0-group abundance of cod. The areas with available optimal temperature were varied for 0-group cod, with limited extension in warm years (Eriksen et al. 2012). While starting in 2008, the abrupt change in the 0-group cod time series, and several strong year classes with the record high year class (2011) cod occurred. At the same time increased number of bottom trawls with higher catches. This most likely due to abundant year classes starts to settle earlier. The spatial distribution of bottom catches showed that abundant year classes distribute wider and in recent years 0-group cod were observed outside pelagic trawl coverage (Figure 4). This may increase uncertainty in abundance indices of 0-group cod. Therefore, the coverage area by pelagic trawls should be expanded eastwards in the northern area.

The survey planning has been sub-optimal due to financial, ship availability and/or other not ecological factors, and unclear definition of objectives has increased conflict between different investigations (Michalsen et al. 2013, Eriksen and Gjørseter (Ed.) 2013). Therefore, it was not possibility to follow changes in environmental and species distribution by increasing effort there. The wider occupation area of 0-group cod in the northern area was recorded by demersal trawling not by standard pelagic trawls. We recommend, that the main focus should be related to survey start and progress: early coverage of southern area with northwards progress may decrease number of uncounted fish and additionally, due to the northern area becomes to be important area with regards to changes, therefore needs superior effort in the pelagic layer, and follow changes, including 0-group cod.

Lack of long term perspectives make difficult to bet on development and implementation of new methodology and technology. The settlement of cod is likely to be connected with temperature condition in the upper water masses (Ozhigin et al. 1999), and 0-group cod, distributing between 0 and 150 m, were recorded on the echosounder (Anon 2010). During survey the upper 50-60m and 10 meter over bottom are covered by pelagic and bottom trawls, correspondently. Therefore, development of new observation and capturing methods is needed to approach the absolute numbers of 0-group cod and be able to cover the whole water column.

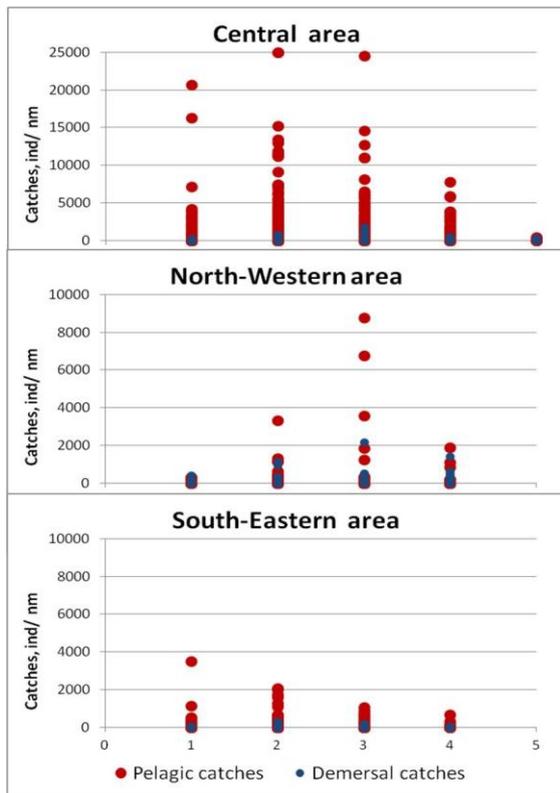


Figure 3. 0-group catches taken by pelagic (red) and bot trawl, split into three areas: the central, which is core are south-eastern and north-western.

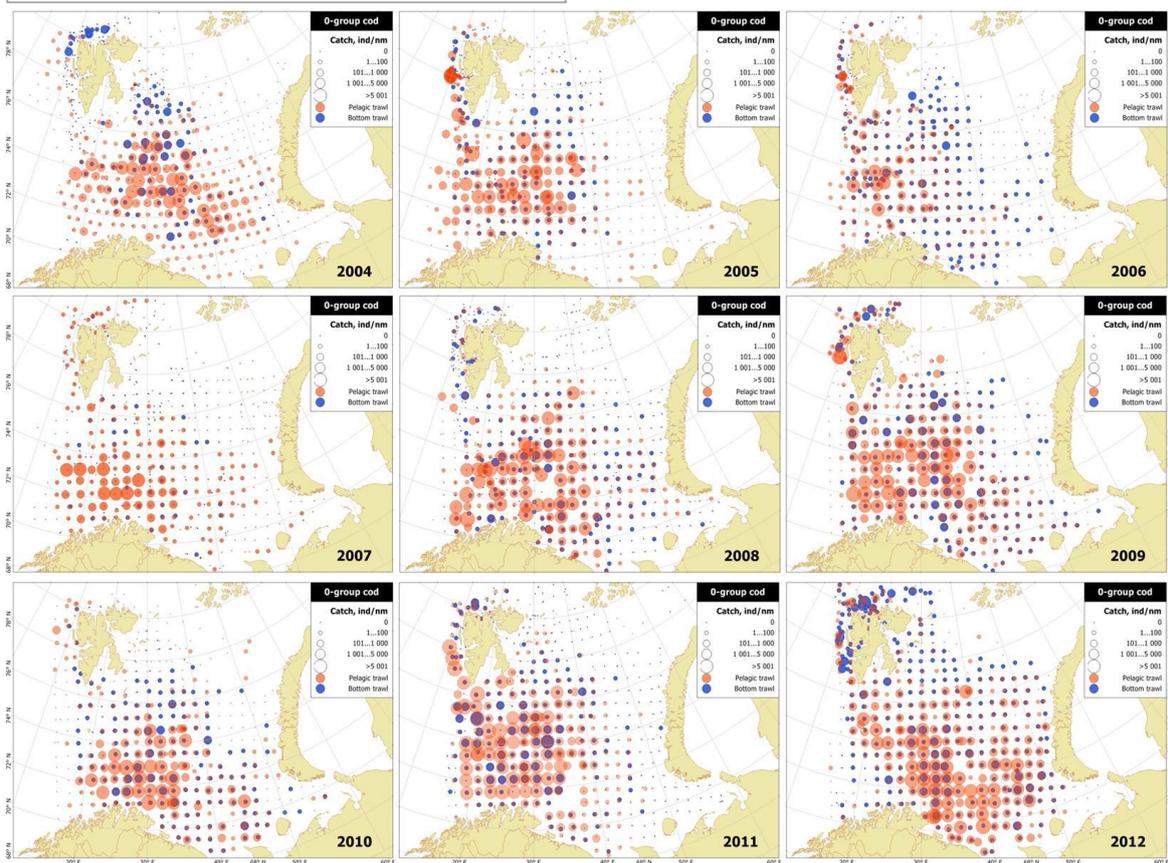


Figure 4. 0-group catches taken by pelagic (red) and bottom (blue) trawl. Higher demersal records than pelagic records at ecosystem station may indicate cod settlement.

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1.6 Pup production survey with subsequent stock assessment of Harp Seals in the Greenland Sea

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Abstract

Harp seals (*Pagophilus groenlandicus*) have been harvested for centuries in the North Atlantic. Estimating abundance and monitoring changes in population size are critical for the management of the species. The ICES management of harp seals requires that the population in question are defined as “data rich” (see Øigård et al. 2013), which means a time series of at least three abundance estimates spanning over a period of 10-15 years with surveys separated by 2-5 years. The most recent abundance estimates should be based on surveys and supporting data (e.g., fecundity and mortality estimates) that are no more than 5 years old. Stocks whose abundance estimates do not meet all these criteria are considered “data poor”, and should be managed more conservatively.

Methods and results

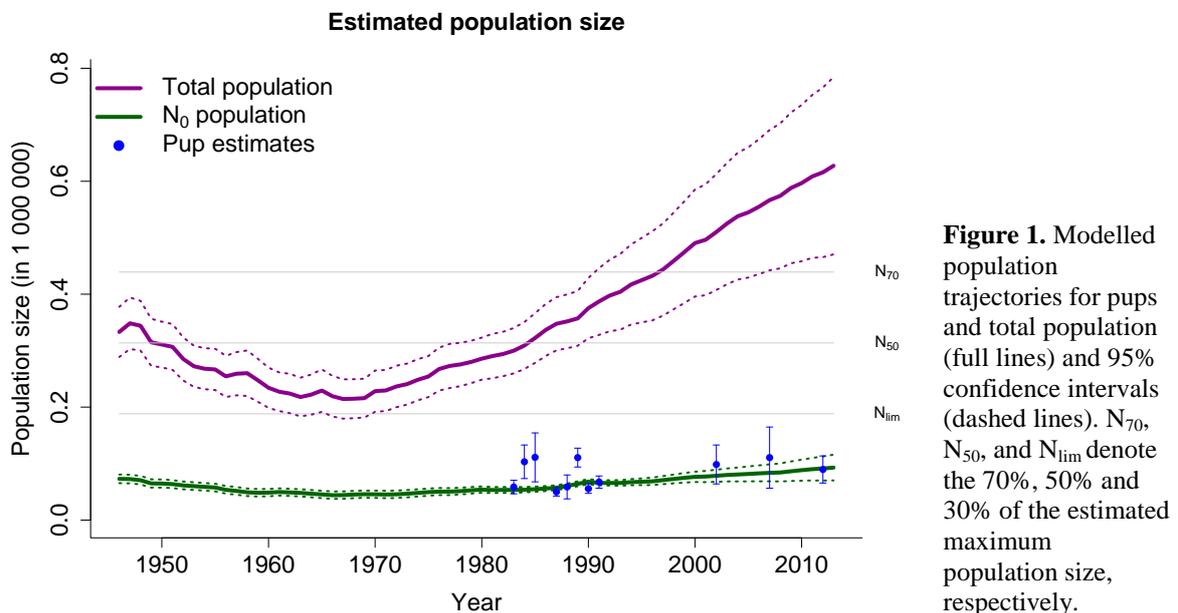
In the period 18 March to 1 April 2012, aerial surveys were conducted in the Greenland Sea pack-ice (the West Ice), to assess the pup production of the Greenland Sea populations of harp and hooded seals (Øigård et al., 2013). Two fixed-wing aircraft, stationed in Constable Pynt (East-Greenland) and Akureyri (Iceland), were used for reconnaissance flights and photographic surveys along transects over the whelping areas. A vessel based helicopter also flew reconnaissance flights, and was subsequently used for monitoring the distribution of seal patches and age-staging of the pups. The reconnaissance surveys were flown between 18 March - 1 April in an area along the eastern ice edge between 67°55' and 74°10'N. The ice edge was close to the Greenland coast in 2012. The reconnaissance surveys, usually flown at altitudes ranging from 160 - 300 m, were adapted to the actual ice configuration. East-west transects spaced 5 or 10 nm apart were flown from the eastern ice edge over the drift ice to the west, usually 20-30 nautical miles (or longer). Harp seal pups were first observed on 19 March in an area between 73°00'N and 73°18'N; 14°28'W and 15°05'W and on 21 March in area between 72°00'N and 72°25'N; 15°30'W and 17°00'W. These two groups drifted together and were subsequently treated as a single patch. Data from the staging surveys were used to estimate the temporal distribution of births, which was used to correct the abundance estimates obtained for seals that might not be born yet, or already left the ice at the time of the photographic survey.

Both aircrafts were equipped with Vexcel Ultracam Xp digital cameras, which provided multichannel images (Red Green Blue Infrared). On 28 March, a total of 27 photo transects, spacing 3 nautical miles, were flown using both aircrafts in the area between 70°43'N / 18° 31' - 18° 15' W and 72° 01'N / 17° 29' - 17° 29 W. The survey covered the

entire area of the merged whelping patches. Coverage along transects was 80-90 %, resulting in a total of 2792 photos. The total pup production estimate obtained for harp seals was 89 590 (SE = 12 310, CV = 13.7%) (Øigård et al., 2013). This estimate is slightly, but not significantly lower, than estimates obtained in similar surveys of the area in 2002 and 2007.

An age-structured population dynamics model is used to estimate abundance and provide catch options for harp seals in the Greenland Sea. The model makes use of historical values of the pregnancy rate (F) available from a Russian long term data set (1959 - 1991) (Frie et al. 2003), and later updated with Norwegian data for 2008 and 2009 (ICES 2013). Pup production estimates are available from mark-recapture estimates (1983-1991, see Øien and Øritsland 1995) and aerial surveys conducted in 2002 (Haug et al., 2006), 2007 (Øigård et al., 2010), and 2012 (Øigård et al., 2013). Catch levels for the period 1946 – 2013 are also used. The model estimates the initial population size, pup mortality, and mortality of all seals aged one year and older.

The modelled population trajectory is shown in Figure 1. The model estimates were stable for various choices of initial values. The model trajectory suggests an increase in the population abundance from the 1970s to the present 2013 abundance of 534 400 (379 200 – 689 600) 1+ animals and 93 010 (70 210 – 115 810) pups. The total population estimate is 627 410 (470 540 – 784 280) seals (Øigård et al., 2013).



The population model had difficulty in capturing the dynamics of the pup production estimates. The predicted population trajectories from the model are driven by the mark-recapture estimates of pup production from the 1980s and early 1990s. There is considerable uncertainty associated with these estimates. Treating these estimates differently could change our predictions of the trajectory of the population.

ICES have developed a Precautionary harvest strategy for the management of harp seals. The strategy includes two precautionary and one conservation (limit) reference levels (see Hammill and Stenson, 2007). The reference levels relate to the pristine population size, which is the population that would be present on average in the absence of exploitation, or a proxy of the pristine population (which in practical terms is referred to as the maximum population size historically estimated from the population model, N_{\max}). A conservation, or lower limit reference point, N_{\lim} , identifies the lowest population size that should be avoided with high probability. The first precautionary reference level is established at 70% (N_{70}) of N_{\max} . When the population is between N_{70} and N_{\max} , various harvest levels could be used, but aiming the population to remain above the N_{70} level. ICES (2008) has suggested that this could be done by designing the total allowable catch (TAC) to satisfy a specific risk criterion which implicate a 0.8 probability of remaining above N_{70} over a 10-year period. When a population falls below the N_{70} level, conservation objectives are required to allow the population to recover to above the precautionary (N_{70}) reference level. N_{50} is a second precautionary reference point where more strict control rules must be implemented, whereas the N_{\lim} reference point, set by ICES (2008) at 30% (N_{30}) of N_{\max} , is the ultimate limit point at which all harvest must stop.

The model indicates an increase of the 1+ population of 28.8% over the next 10 years under the scenario of no hunt. If current catch level of 5 941 seals (average the last 5 years and containing 59.9% pups) is continued the model predictions indicates an increase in the 1+ population of 21% over the next 10 years. The model estimates that an annual catch level of 20 429 seals (assuming 59.9% pups) would stabilize the population size at present level. Current total population size is the largest population size observed and is thus used as N_{\max} in the management regime. If the annual catch level was 30 988 seals (assuming 59.9% pups) the population will be reduced to N_{70} with probability 0.8 within 10 years (Øigård et al., 2013).

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1.7 Research of the White/Barents Seas Harp Seal Population on Whelping Patches with Use of Multispectral Air Surveys

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Purpose of researches

Rough data collection for study of the White/Barents Seas harp seal pups distribution and numbers in whelping time. In future this data use for total pup production number calculation and then this information uses in modeled calculation of population size.

Method

For this purpose uses equipment which work in optical and infrared ranges electromagnetic wavelengths, and this technology was named as multispectral. Above equipment install onboard aircraft. The main area of research is the White Sea and adjacent waters of the Barents Sea south-eastern part, and time is March but no later than March 24. Research flights carry out along transects which are oriented along longitudes with distance between its no more than 10 km from flight altitude no less than 200 m standard is 250-300 m. After flights rough data (images) process by special PINRO approach and method. After that makes calculation on total pup production abundance assessment.

Results. Under results of considered researches at present the White/Barents Seas harp seal pup production numbers has stable low level values, in 2005 it was 122 700, in 2008 - 123 100, in 2009 - 156 600, in 2010 and 2011 - 163032. In 2005 was recorded the lowest modern level of pup production abundance. Under carried out additional and special research the main reason that was climatic changes in the Russian Arctic west part. Here was recorded warmer that cased decrease of ice cover area and ice season duration in comparing with end of 1990-s years and 2000-s beginning when was recorded the White Sea harp seal population pup production modern maximum.

Conclusion

All above results in ICES/NAFO WG on harp and hooded seals were presented where it was took and used for future modeled calculation of total stock the White/Barents Seas harp seal population.

1.8 Evaluation of the sampling strategy for the Norwegian-Russian 0-group component of the ecosystem summer survey

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Abstract

It appears that for the 0-group component of the Ecosystem survey, too many fish are measured from each station. For example, even though 15,531 0-group cod were measured in 2012, the effective sample size for estimating the mean length was only 399 fish. It follows that if 20 cod had been measured at each station for a total of 3960 fish in 2012, then the standard error for the estimate of mean length would equal 0.62, as compared with 0.61 for the estimate based on 15,531 cod. Similar results hold for 0-group capelin and herring, that is the precision of estimates of the length distribution of 0-group fish would be reduced only slightly if samples sizes were significantly reduced.

Introduction

The region covered by the Ecosystem survey in the Barents Sea consists of three major subareas; the Norwegian Zone, the Russian Zone, and the International Zone. In these three subareas, the survey stations are mainly chosen based on a stratified systematic design, that is in each stratum the stations form a grid, of equally spaced grid points in each direction, except north of Svalbard where the stations are chosen using a stratified random design with stratum defined by depth zones (Figure 1). At each station the 0-group fish (cod, capelin, herring and haddock) caught are collected or subsampled from the group or "cluster" of fish collected by the mid-water "Harstadål" trawl.

Fish (or flora and fauna in general) of a particular species sampled during the ecosystem survey is not a random sample of individual fish from the entire population but a sample of n clusters, one cluster from each station. Since fish caught together are usually more similar than those in the general population, a total of m fish collected from n clusters will contain less information about the distribution of the variable of interest for the entire population than if m fish were randomly sampled from the population – which is impossible to do in practice.

One measure of the amount information in a sample from a complex sampling scheme is the *effective sample size*, which is defined as the number of individuals that would need to be sampled at random so that the estimates generated by simple random sampling would have had the same precision as the estimates obtained based on the more complex sampling scheme (Kish, 1965; Skinner et al., 1989; Faes et al., 2009). In particular, the effective sample size is a transparent and efficient way to measure the amount of

information for estimating, say, mean age or length contained in a cluster sample from marine surveys (Pennington et al., 2001).

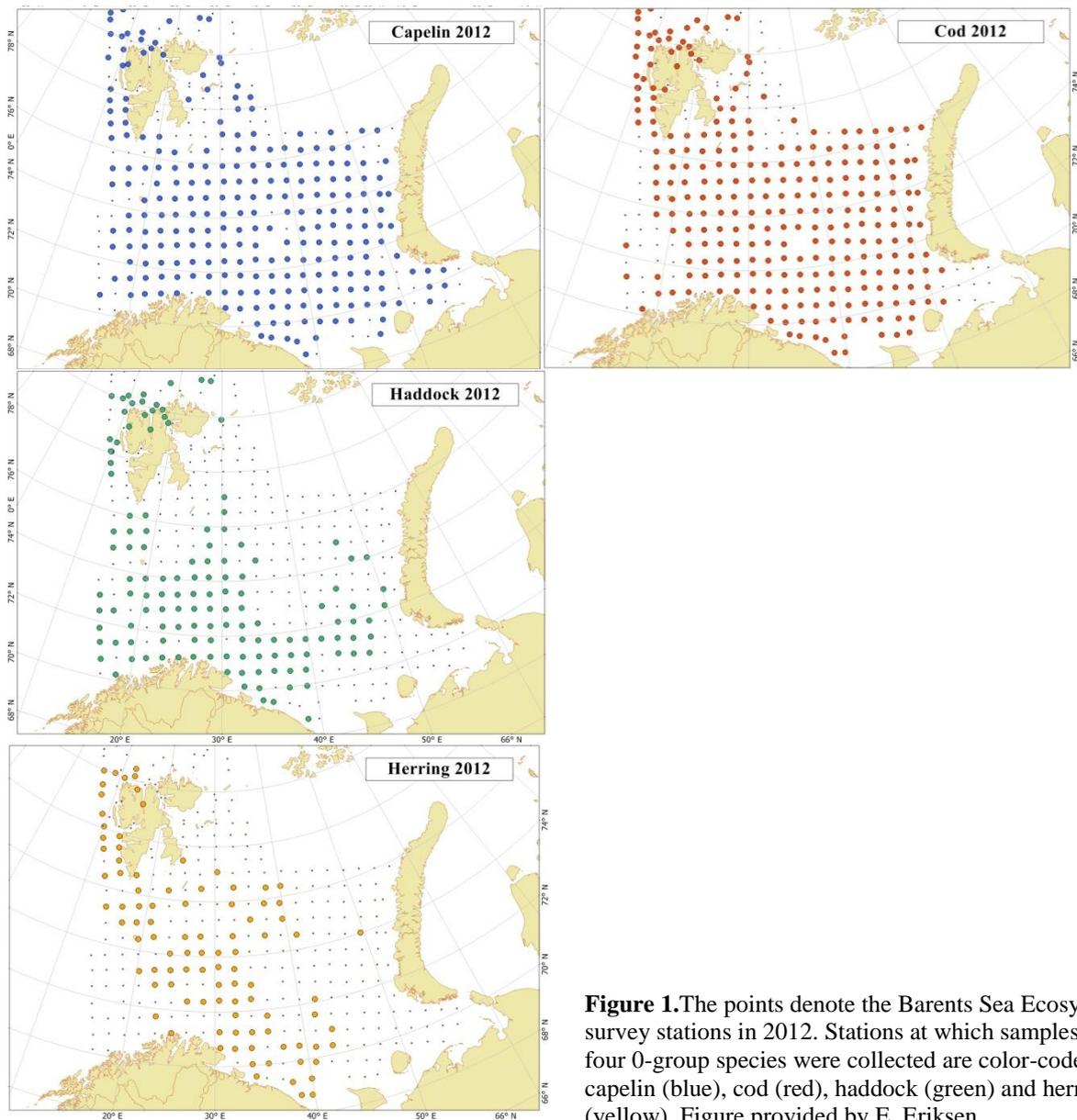


Figure 1. The points denote the Barents Sea Ecosy survey stations in 2012. Stations at which samples four 0-group species were collected are color-code capelin (blue), cod (red), haddock (green) and herr (yellow). Figure provided by E. Eriksen.

The effective sample size is a much more informative number about the amount of information contained in a sample than is the total number of fish that were measured or aged from n clusters. For example, Table 1 (from Pennington, et al., 2002) shows the sampling efficiency for estimating the mean length of cod based on data from the summer survey in the Barents Sea (now called the Ecosystem survey) and from the joint Russian-Norwegian winter survey. For instance, 46 593 Northeast Arctic cod were measured in 1999, while the effective sample size was only 211 fish. The relatively small effective sizes are reflected in the estimated variance of the means, which are rather large given the number of fish that were measured.

Figures 2 and 3 demonstrate the typical outcome of reducing the number Northeast Arctic cod measured or aged at each station during the 1999 survey. Figure 1 shows the variability in the estimates of the effective sample size along with the variability of estimates of the mean length based on three subsample sizes.

Table 1

Summary statistics for assessing the precision of the estimated length distributions of Northeast Arctic cod based on the winter and summer bottom trawl surveys in the Barents Sea. The estimated effective sample size is denoted by \hat{m}_{eff} , n is the number of stations at which cod were caught, M is the total number of cod caught, m is the number measured, \hat{R} is the estimate of mean length, and $\text{var}(\hat{R})$ is its variance.

Year	n	M	m	\hat{R} (cm)	$\text{var}(\hat{R})$	\hat{m}_{eff}	\hat{m}_{eff}/n	$(\hat{m}_{eff}/m) \times 100\%$
Winter								
1995	296	175006	47286	20.0	0.7	313	1.1	0.7
1996	314	209114	44021	18.0	0.3	511	1.6	1.1
1997	177	71418	25689	19.0	2.1	119	0.7	0.7
1998	197	60746	32536	22.1	0.7	394	2.0	1.2
1999	223	50192	21760	25.0	1.9	107	0.5	0.5
	Avg.	113295	34258			289	1.2	0.8
Summer								
1995	329	66643	46161	31.2	1.4	252	0.8	0.6
1996	341	115834	45286	24.4	0.6	478	1.4	1.1
1997	266	72093	26947	23.1	0.8	266	1.0	1.0
1998	218	72360	23461	25.1	1.1	184	0.8	0.8
1999	217	46593	23253	30.8	0.9	211	0.9	0.9
	Avg.	74705	33022			278	1.0	0.9

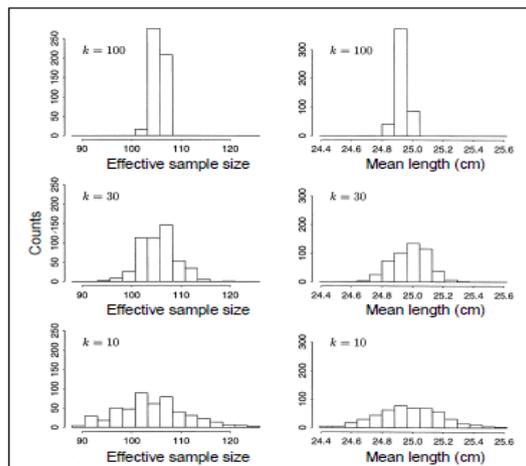


Figure 2

Simulated estimates of the distribution of the effective sample size, \hat{m}_{eff} , and of the mean length, \hat{R} , when the total number of fish measured is reduced for the 1999 winter survey in the Barents Sea. The top panel is when a maximum of $k = 100$ fish are selected per subsample for a total of $m = 17,615$ fish in each run; the middle panel, $k = 30$, $m = 7240$; and the bottom panel, $k = 10$, $m = 2597$. The estimate of the population mean based on the entire sample ($m=21,769$) is 24.96 and its 95% confidence interval is (22.26, 27.66).

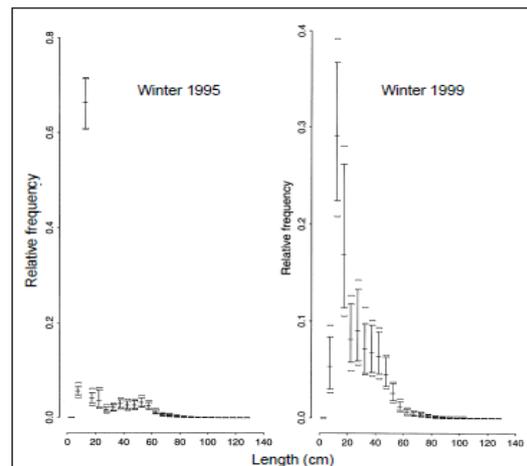


Figure 3

Bootstrapped estimates of the 95% confidence intervals for the proportion of cod in the Barents Sea in each 5-cm length bin, for winter 1995 and for winter 1999. The inner brackets denote the confidence intervals if the estimates are based on all the cod measured during the surveys and the outer brackets denote the confidence intervals if 10 fish are measured for each subsample.

The 95% confidence limits for each length class based on the entire sample are rather wide (Figure 2), which demonstrates that a small effective sample size implies that the estimate of the entire population distribution is rather imprecise. In addition, as shown in the Figure 2, the length of the 95% confidence intervals decrease only marginally if the number of cod measured is reduced from 21 769 to 2597.

In this note the efficiency and suitability of the present sampling intensity for the 0-group component of the Ecosystem survey is evaluated based on estimates of the effective sample sizes. Furthermore, based on estimates of the between station variability and the within station variability, the effect of reducing the sample size at a station is evaluated.

Assessing 0-group sampling intensities

Methods

In order to evaluate the overall efficiency of the current sampling intensities for 0-group fish during the Ecosystem survey, estimates of effective sample sizes for estimating the mean length, $\hat{\mu}_l$, were calculated. In particular, if the variance of the estimator of $\hat{\mu}_l$ is denoted by $\text{var}(\hat{\mu}_l)$, and the variance of the length distribution is denoted by $\hat{\sigma}_l^2$, then the estimated effective sample size, \hat{m}_{eff} , is defined by

$$\frac{\hat{\sigma}_l^2}{\hat{m}_{eff}} = \text{var}(\hat{\mu}_l),$$

or

$$\hat{m}_{eff} = \frac{\hat{\sigma}_l^2}{\text{var}(\hat{\mu}_l)}.$$

It should be noted that if the effective sample size is small, then this implies that the estimate of the entire distribution is rather imprecise as shown by the example in Figure 3. For details on calculating the effective sample size for marine cluster samples see, e.g., Pennington and Vølstad (1994), Folmer and Pennington (2000); Pennington et al. (2002); and Chih, (2011).

A variance component analysis (see, e.g., Box *et al.*, 1978; Pennington and Helle, 2011) was used to quantify the contribution to the total variance of estimates of mean length for 0-group fish by the station to station variance and by the within station variance. Based on these estimates an efficient sampling scheme can be selected

If y is the length of a 0-group fish, then its length can be expressed as follows:

$$y = \mu + \varepsilon_s + \varepsilon_{ws},$$

where μ denotes the mean length of the entire population surveyed, ε_s (the station component) which is the difference between the mean length of fish caught at station, s , and the grand mean, μ , and ε_{ws} is the within station component. Since the station and the within station sampling are independent, the variance of y is given by:

$$\text{Var}(y) = \sigma_s^2 + \sigma_{ws}^2.$$

Then assuming sampling is balanced (and ignoring the within station finite population correction factors), the variance of the unweighted estimator of the mean length $\hat{\mu}$ (see, e.g., Cochran, 1977) is given by

$$\text{Var}(\hat{\mu}) = \frac{\sigma_s^2}{n} + \frac{\sigma_{ws}^2}{nk},$$

where n is the number of stations at which samples were collected, and k is the number of fish measured (or aged) at each station. Even though in practice the sampling of 0-group fish is not balanced, and the mean should be estimated using a weighted estimator, Equation (4) provides a good approximation of the relative efficiency of varying sampling intensities (Pennington and Helle, 2011).

Evaluation of sample sizes for the 0-group Ecosystem component

In Figure 4 are plots of the estimated length distribution of 0-group cod, capelin, herring and haddock based on data from the 2012 Ecosystem survey. The estimated length distributions are fairly “bell shaped”, which would be expected if the entire age distribution was sampled.

The effective sample sizes (from Equation 1) for estimating mean length in 2012 were relative small for all the four 0-group species surveyed by the ecosystem survey (Table 2). The average effective sample was approximately one fish per station (last column in Table 2), which is also the typical average effective sample size for surveys of older fish (Pennington, et al., 2001).

In Table 3 are estimates of the variance components for the four species. It should be noted that the between station component is rather large for each species. This is significant because the number of stations at which fish are sampled sets a lower bound on the attainable precision: that is, from Equation 4 it follows that; $\text{Var}(\hat{\mu}) \geq \sigma_s^2 / n$ no matter how many fish are sampled at each station.

Table 2. Summary statistics for estimating the effective sample sizes in 2012 for 0-group cod capelin herring and haddock based on the Ecosystem survey.

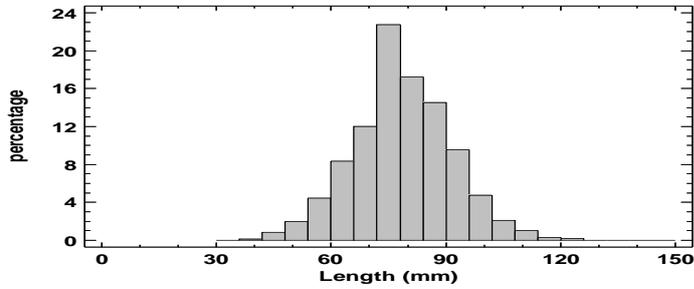
Species	No. of stations (n)	Sample size	Est. mean length ($\hat{\mu}_l$)	$\text{var}(\hat{\mu}_l)$	Variance of length distribution ($\hat{\sigma}_l^2$)	Effective sample size (\hat{m}_{eff})	\hat{m}_{eff} / n
Cod	198	15,531	79.0	0.41	163.4	399	2.02
Capelin	197	10,639	48.1	0.24	68.4	285	1.45
Herring	99	3,586	57.7	0.49	41.2	84	0.85
Haddock	160	938	89.6	3.23	310.0	97	0.61

Table 3. The estimated variance components for fish length (Equation 3) based on the ecosystem 0-group survey data in 2012.

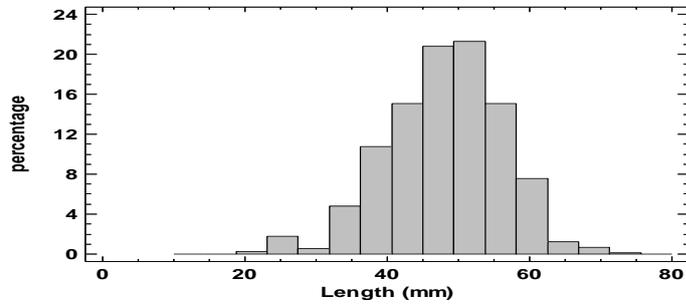
Species	Between station component	Percent of total variance	Within station component	Percent of total variance	Average number of samples per

	$\hat{\sigma}_s^2$		$\hat{\sigma}_{ws}^2$		station
Cod	71.8	43.8%	92.0	56.2%	97
Capelin	40.6	59.1%	28.2	40.9%	54
Herring	21.7	52.0%	20.0	48.0%	36
Haddock	214.1	67.9%	101.1	32.1%	6

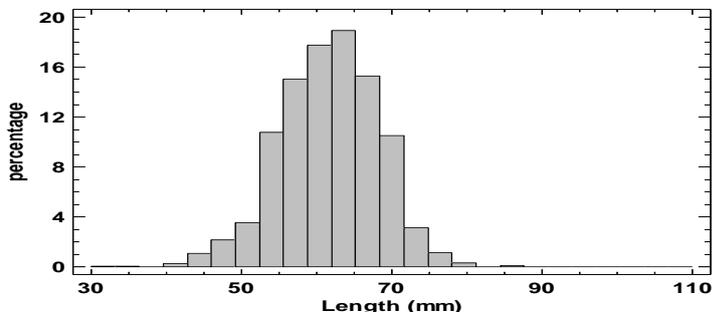
Cod



Capelin



Herring



Haddock

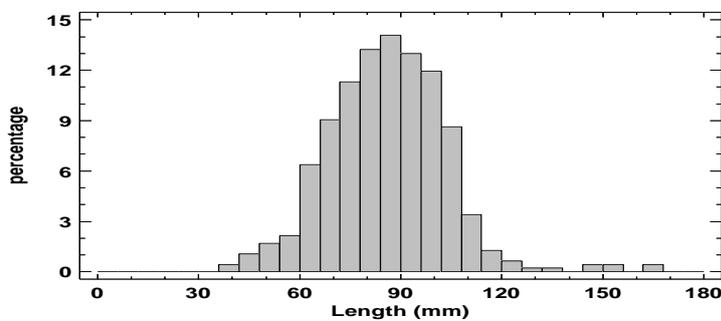


Figure 4. Estimated length distribution of 0-group cod, capelin, herring and haddock in 2012.

In Table 4 are the likely change in the precision of estimates of mean length of 0-group cod, capelin and herring for two sampling scenarios; reducing sample size to 20 or 10 sampled fish per station. Haddock was excluded since the average number sampled at each

station was 6 fish (Table 3). Again, the main reason that little precision was lost by reducing sampling at a station was because the between station component was relatively large.

Table 4. Estimated standard error (*s.e.*) for estimating the mean length based on Equation 4 for three sampling scenarios. In parentheses is the number of 0-group fish measured for each scenario.

Species	If sampling were balanced in 2012 <i>s.e.</i> ($\hat{\mu}_l$)	Sample 20 fish per station <i>s.e.</i> ($\hat{\mu}_l$)	Sample 10 fish per station <i>s.e.</i> ($\hat{\mu}_l$)
Cod	0.61 (15, 444)	0.62 (3,960)	0.64 (1,980)
Capelin	0.46 (10,638)	0.46 (3,940)	0.47 (1,970)
Herring	0.47 (3,564)	0.48 (1,980)	0.49 (990)

Discussion and conclusions

The reason that the effective sample sizes were small (approximately one fish per station) compared with the total number of fish measured is that 0-group fish caught at a station tend to be more similar to each other than those in the entire population, i.e. there is positive intra-cluster correlation (Cochran, 1977). However an effective sample size of one fish per tow does not mean only one fish should be measured at each station (Pennington et al., 2002; Aanes and Pennington, 2003), but implies that the only way to improve survey precision significantly is to increase the number of stations, i.e. sample fish from as many locations as possible. In general, if intra-cluster correlation is positive for an attribute, then it is usually best to take a small sample from as many locations as feasible (see, e.g., Gunderson, 1993; Bogstad et al., 1995; McGarvey and Pennington, 2001).

For the sake of brevity, only data from 2012 was presented in this report, but similar results hold for the other years surveyed. In particular, it should be noted that positive intra-cluster correlation for many characteristics (e.g., age, stomach contents, etc.) appears to be the norm for marine surveys (see, e.g., Pennington, 2002).

In summary, the effective sample sizes were small compared with the number of fish sampled (Table 2), which implies that too many 0-group fish are sampled at a station. Additionally, it appears that precision will decrease only slightly if the number fish sampled at each of the ecosystem stations is reduced. Reducing the sampling intensity would save survey time that could be used to improve the efficiency and accuracy of the data collection procedures.

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1.9 Development of the trawl-acoustic survey for blue whiting in the spawning grounds to the west of the British Isles

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Blue whiting *Micromesistius poutassou* (Risso) plays a great role in the fishery of many countries in the European North. In the Northeast Atlantic, the distribution area of blue whiting is wide, and only in the spawning period, the fish are concentrated in the relatively small area to the west of the British Isles. Since 1971, in the spawning area of blue whiting, the trawl-acoustic survey (TAS) has been conducted. During the recent 40 years, the TAS for blue whiting has been developed from national to international survey in which 5-6 research vessels from different countries participate. The data on the fish abundance and biology obtained during TAS serve as the basis to develop recommendations on the stock management.

During the last 40 years, scientists developed the survey methods trying to provide the maximal possible reliability of the study results. So, changed were the survey plan, fishing gears, fish registration devices, fish target strength and methods to process the results. The paper attempts to clear up how the efforts of scientists from different countries allowed the survey quality and reliability to be improved.

1.10 History and evolution of the russian Barents sea autumn-winter multispecies trawl-acoustic survey.

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The scientific value of any survey data is depending inter alia on unchangeable and successive methods, as well as duration and continuity of observation series.

Surveys for cod and haddock juveniles have been conducted by PINRO since 1946, and up to 1981 there had been the two estimation periods, September-October and November-December. In 1982, the investigations were transformed to the Russian Autumn-Winter multispecies trawl-acoustic survey (MS TAS) for assessment of juveniles and estimation of the main commercial Barents Sea stocks indices which have been limited only by November-December period.

The route of each survey, periods and a number of stations are assigned depending on target commercial species distribution.

Initially, the survey methods envisaged one hour tows. But, since 2006, half an hour tows have performed in the areas with the depths of less than 500 m. The reduction of tow duration allows to decrease gear accidence, to speed up catch processing and area investigation, but, at the same time, catch species diversity reduces and, especially, in relation to the non-abundant species.

The main purpose of MS TAS is to calculate the relative abundance indices for cod, haddock and Greenland halibut in order to adjust VPA when estimating stocks at the ICES Arctic Fisheries Working Group. To determine the quality of data the preliminary estimation of the internal correlation of all indices is made and the correspondence of this or that index to common trends is calculated.

This paper is aimed at reviewing the changes during the surveys methods and analyzing the influence of those changes on the quality of data obtained.

1.11 Sexual dimorphism in relation to technical measurements and gear selectivity in Greenland halibut trawl fisheries in the Barents Sea.

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Substantial sexual dimorphism is apparent in Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum, 1792)). In this study we examine this regarding differences in length at maturity and proportion of abundance by length found at the continental slope, where both spawning grounds and main fishing grounds are found. The females are considerably larger when they mature and reach a larger maximum size compared to the males. Thus the minimum legal catch length will both influence the sex composition of the spawning stock as well as the utilization of individual growth potential of immature fish. This complicates the choice of minimum length.

The traditional view based on yield per recruit (Y/R) and spawning stock biomass per recruit (P/R) analysis would be to set minimum size such that one avoids fishing on immature females. However as length at maturity found for females (mL50=57 cm) is substantially higher than that found for males (mL50=42 cm) this would imply that fishing pressure would be disproportionately concentrated on mature females. This is unfortunate regarding size of female spawning biomass and can increase risk for recruitment overfishing. It is argued that minimum legal size for Greenland halibut should be a compromise between the above considerations.

Results from selection experiments on the RV “Vilnius” April-May 2011 survey are shown and indicate that none of the examined selection gear alternatives were fully suitable to satisfactorily give selection according to the current minimum legal size for Greenland halibut in the Barents Sea. However, the experiments were too limited to give a clear conclusion.

Analysis in the study are based on the current survey and other surveys and experimental trawl fisheries that cover the depths and area for the main fishing grounds for direct fisheries for Greenland halibut.

We found that further studies are needed to conclude on gear selection in the trawl fisheries of Greenland halibut in the Barents Sea. These studies might involve experiments with modifications of lifting panel in selection grids and should be conducted in the most appropriate time and areas.

We can conclude that given the substantial sexual dimorphism for Greenland halibut the current minimum legal size of 45 cm might be suitable to utilise juvenile growth potential and minimise fishing pressure on the smallest immature females, and still avoid allocating too much fishing pressure on the largest females in the trawl fisheries.

1.12 MAREANO, a national mapping programme documenting bottom topography, the environment and bottom fauna on the continental shelf and slope of Northern Norway

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Information about the distribution, composition and status of the benthic environment and communities is important for the implementation of ecosystem-based management involving assessment of the effects of human activities. The MAREANO programme (Marine Areal Database for Norwegian Coasts and Sea Areas) conducts seabed mapping in order to fill knowledge gaps in relation to the implementation of management plans for the Norwegian EEZ. This paper describes the experience from the mapping strategy used by MAREANO. By using a variety of sampling gears the benthic environment and communities from all types of seabed are thoroughly documented. This involves the mapping of bottom topography, seabed substratum, pollutants, species composition, biomass and habitat forming vulnerable biota in a varied marine landscape. The area mapped from 2006 to 2013 is 131,000 km², spans depths ranging from 40 to 2700 m and covers a variety of topographic features including canyons, cold seeps and coral reefs. The information gained by this broad mapping approach has offered a unique insight into the diversity of benthic species and habitats. Through interpretation and classification of the information gained MAREANO scientists produce a database and detailed maps of seabed surficial geology, marine landscapes, biotopes and particularly sensitive and threatened habitats. Indicators of human impact, such as pollutants, trawl marks and marine litter are also presented on maps. Experience from 8 years of detailed mapping shows the necessity of thorough mapping for informed management decision-making.

This paper was published in the journal: Marine Biology Research.

Buhl-Mortensen L, Buhl-Mortensen P, Dolan MFJ and Holte B 2014. The MAREANO programme – A full coverage mapping of the Norwegian off-shore benthic environment and fauna. Marine Biology Research, Volume 11, Issue 1, 2015.

<http://www.tandfonline.com/eprint/VJ44CzmqgrCwvWuziHrf/full>

1.13 The Barents Sea ecosystem survey: fish assemblages in the Svalbard sub-area.

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Fish assemblages in the Barents Sea has been covered by the ecosystem survey in August-September 2004-2012 as a cooperation between Institute of Marine Research, Norway and PINRO, Russia, and the survey has covered most of the ice free parts of this area. The area around Svalbard (Spitsbergen) has mostly been covered by a depth-stratified trawl station design whereas the remainder of the area has been covered by stations in a regular grid. Changes in bottom temperature affects the local fish community and these changes can be difficult to reveal on a short time scale. However, by using a simple depth-stratified survey design, variation in fish assemblages can be exposed and monitored. We analyzed the survey data from Norwegian vessels in the sub-area around Svalbard to investigate the variability in the demersal fish assemblages in relation to the depth stratification and bottom temperature. The distribution of species composition of the stations strongly reflects the bottom temperature and depth.

1.14 Significance of cod settlement on 0-group cod abundance indices, and how reduce this.

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0-group investigations in the Barents Sea have been carried out since 1965 and aimed to get the first indication of the year class strength for several commercial and ecologically important fish species, including cod. Since 1980, the standard trawling procedures were used on all Russians and Norwegians vessels. The 0-group abundance indices based on stratified sample mean method, and are utilized indirectly in the fish stock assessment, recruitment studies and ecosystem modelling. However the estimation of settlement of 0-group cod during survey has not been established. Since 2004 there has been conducted simultaneously pelagic and the demersal observations, and these showed that the cod may start settlement in August and September and that process varied between years and areas. However, this component consist only 0.2 -1.1% of total numbers, with 0.5% on average, and therefore too small to influence significantly abundance indices. Suggestions for improvement of survey (the spatial and temporal coverage) and estimation methodology are made.

Theme session 2: Index calculations

2.1 Uncertainty in estimates of density and biomass of Norwegian spring spawning herring based on combined acoustic and trawl surveys.

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Norwegian spring spawning herring (NSSH) is the largest herring stock in the world, with the highest estimate of the spawning stock biomass (SSB) at 16 million metric tons in 1945. The most recent estimate of the spawning stock (2012) was 6 million tons. NSSH is assessed by using a VPA to estimate fishing mortality (F) and SSB, with several survey indices of abundance used as tuning series. However, the ICES coordinated international ecosystem survey in the Nordic Seas (IESNS), conducted annually in May by EU, Iceland, Faroe Islands, Norway and Russia (Barents Sea), is the only survey that produces an age specific tuning series for the SSB. The IESNS survey produces an estimate of numbers at age based on acoustics and targeted trawling, and has since 1995 had a high influence on the assessment and the advice on total allowable catch. The IESNS survey follows a stratified systematic design, where three subareas (strata) are covered by systematic acoustic transects with varying degree of overlap between the vessels from the different nations. Until now, the results from the survey have been reported without any estimate of uncertainty of the estimates. We analyzed the survey data as a stratified multi-stage survey, with acoustic transects as primary sampling units, and biological trawl samples as secondary sampling units, and under the assumption of simple random sampling in the first stage. Strata one includes three transects while strata two and three include seven transects, respectively. We first derived acoustic estimates of density and biomass for each transect, and then estimated the stratified mean abundance indices and biomass by age class (1-18) and overall (1+). The variance and relative standard errors ($RSE=SE/mean$) of the abundance indices and biomass estimates were based on bootstrapping of PSUs, using the R survey package. The estimated RSE for mean density in numbers per age and mean biomass/area by age (year classes 1-18) ranged from 13% to 98%, with the least precise estimates for young and older fish. The overall density and biomass was estimated with a precision of $RSE= 15\%$.

2.2 Probability based estimates of a demersal trawl survey.

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The Barents Sea (international) winter survey is conducted annually in the first quarter. This article describes how probability based estimators are derived for trawl surveys and how this extends into the estimation of population level processes and parameters using the winter survey data as example. Different weighting factors used in estimation is assigned to single fish samples and the sums of such factors are the abundance indices themselves. Several diagnostics are suggested and it is shown how these will give the information needed to optimize the survey design given certain assumptions. Estimates of variance are obtained by a stratified bootstrap approach ignoring the additional variation from catches being subsamples.

2.3 Variance and estimates of number of individuals from acoustic surveys.

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In standard acoustic biomass surveys the acoustic backscattering is allocated to different fish species by examining the echograms and the species composition in the trawl catches or other types of sampling gear. The acoustic abundance (m^2/nm^2) by species and stratum is estimated with sampling variance by using a stratified transect design. The estimation of population characteristic such as length and age distributions is more statistical challenging, as these samples often are derived from non-designed on-target trawling. Here, we present an objective method to link trawl stations to the acoustic samples in a stratum, which enable a conversion of acoustic abundance into numbers of fish by length groups and other population categories such as numbers at age or sex. In our routine, all trawl stations search for acoustic samples within a defined range, and an individual weight is derived for each of the trawl stations that are assigned to the acoustic samples within a stratum. The individual weight is calculated as the sum of echo abundance in stratum (i) that is in the range of the trawl station divided by the total sum of echo abundance in the i 'th stratum. By combining a Monte Carlo simulation of the acoustic abundance estimate with a bootstrap approach to the trawl samples we are able to estimate numbers of fish by length groups and other population categories; where all point estimates can be given with their corresponding estimates of variance.

2.4 “StoX” – an open source approach to survey calculations.

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Abstract

A new infrastructure for survey data is developed at the Institute of Marine Research, Norway. It includes software modules to create specific data-products from survey data. One of the modules currently being developed is “StoX”, which is intended for calculation of standardized, quality-assured stock size indices from trawl or acoustic data. This software will replace the programs being used hitherto; “Beam” for acoustic (Totland and Godø, 2001) and “Survey” for trawl indices (Jakobsen *et al.*, 1997).

Only open source software is used for development of the program and Java forms the basis. The program is a stand-alone application for easy sharing and further development in cooperation with other institutes.

The core of the program is a library of functions, which each performs a defined estimation operation. Each function reads one or more input data sets as well as input parameters. The parameters determine the execution behaviour of the function. Function output data sets are available in memory or on file, and are used as input data for subsequent functions. Which functions to use and their order of execution is determined by the setup of the process file. A step in the index calculation may be done in different ways. For this reason, the library may contain several functions with similar purpose, but using different methods to achieve the same goal.

The execution of an index calculation can be governed from the “StoX” user interface, or by accessing the Java function library and process file using external software like R. The graphical user interface contains an interactive GIS module. Accessing “StoX” from external software may be an efficient way to process time series or to perform bootstrapping on one dataset, where for each run, the parameter content of the process file is altered.

Experts specification demands, documentation and statistical rigorousness have been essential for the development of “StoX”.

Introduction

A major challenge for many organizations within fisheries science is to operationalize new methods and technology. National research councils often fund activities related to methods development and takes it for granted that the methods are being implemented. The

operational sides of these organizations have heavy workloads and operationalizing new methodologies are costly.

At present, a new infrastructure for survey data is developed at the Institute of Marine Research (IMR), Norway, called Sea2Data (S2D) (Handegard et al., 2013). In addition to databases (for both reference and survey data), this infrastructure includes software to input, edit and retrieve data from these databases. In addition, software modules are built for the purpose of standardized analyses of these data. The present paper deals with one such module, “StoX” that facilitates the calculation of stock indices. Open source software is used for development of the program and Java forms the basis. Although seen as a part of the new S2D infrastructure, the program StoX is a stand-alone application for easy sharing and further development in cooperation with other institutes.

The approach is built around a core library of functions, which each performs a defined operation for the data processing. The objective is that the library could be shared between the estimation processes for similar data products. Another core idea is that data and calculations are inherently connected, and each calculation step utilizes both data as well as calculation parameters, where the parameters determine the execution behaviour of the function. The resulting calculations are a combination of both the data, function and processing parameters. Calculations from a processing step is used as input data for subsequent steps. The organization and order of the processing steps are determined by a process recipe. A step in the processing path to a final data product may be achieved in different ways, and several alternative calculation steps may be invoked by the process recipe. This results in a complete documentation of the data flow from raw data and processing parameters to the final data product.

Together with establishment of data flux and function developments, there is a large focus on sound sampling design, which is an essential part of all experiments and surveys where the data collections ideally follow well planned designs. Without a clear metadata description of the survey objectives, survey design, sampling units and validity codes for the sampling units, no statistical sound inference about the population can be made. This metadata information needs to be stored and linked to the sampling data, which typically will be done by tagging techniques. A proper tagging of sampling data ensures the development of automatic procedures for estimating a range of population parameters both within and between surveys. Simple filtering processes will select data belonging to defined primary sampling units, strata, and time series.

The execution of the further processing steps may be governed from the “StoX” user interface itself, or alternatively by accessing the Java function library and parameter set using external software like R, Matlab or Python. The user interface contains an interactive GIS module. Accessing “StoX” from external software is an efficient way to process time series or to perform bootstrapping exercises on the whole data product calculation chain, where for each run, the parameters or processing steps are altered.

The objective of this paper is to describe the concept in detail and to explain how this is implemented to create specific data-products from survey data.

Methods and approach

StoX an infrastructure for various index calculations

The purpose of the StoX application

The StoX application is a software infrastructure design to host a variety of different index calculation methods. Such calculations might be different types of acoustic and swept area abundance indices. To facilitate this variety of tasks, strong focus has been on flexibility and modularity during development of StoX. The main objective of StoX is to produce quality-controlled standardized stock size indices, but user defined calculations can also be performed.

Stand alone application

StoX is a stand-alone application which is only loosely dependent on external infrastructure such as input data of a given format. Connectability to new external data sources can easily be extended. Only open source software is used for development. All this forms the basis for sharing and further cooperative development with other institutes.

External input data (trawl, acoustic etc.) can be read from a variety of file formats and databases. The data reading capability is easily expandable.

The most used geographical data, like strata systems, come as a part of the installation. The geographic data exist in common formats and new data can be appended by the user or included in coming installation packages.

Main concept

The StoX application is made up by three main components as shown in Figure 1; A) user interfaces, B) data input and output, C) the core calculations. In this section, the focus is on the core calculation part of the software.

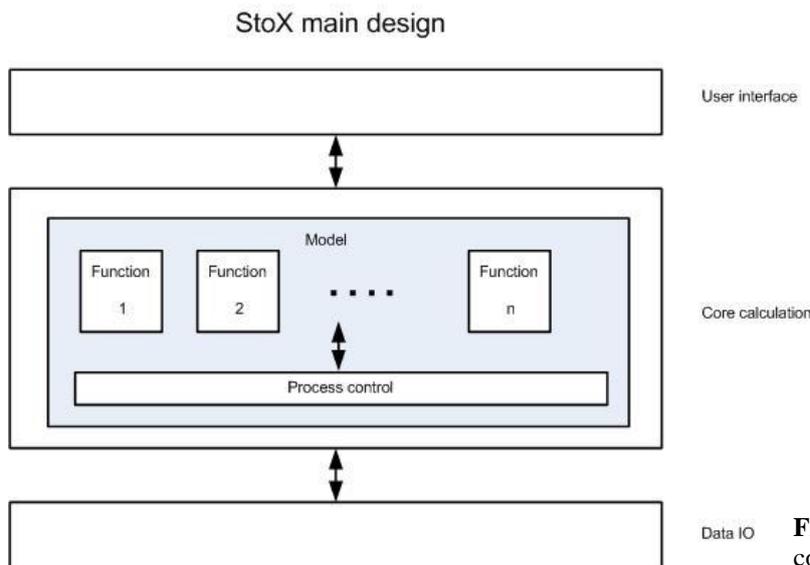


Figure 1. The StoX main conceptual design.

Model, functions, process file and parameters

When a specific type of index calculation is to be performed, a “model” facilitating the tasks and a description on how they are to be executed is used. A model is as shown in Figure 1, a combination of a set of available calculation functions/tasks and a process control file. To produce the index, tasks have to be performed one by one in a sequential order. In addition to containing input parameters to each of the functions in a model, the process file also define the order of the functions execution.

Each function reads one or more input data sets, process and output intermediate data. The input data to a function may origin from an external source like a file or a database (e.g. trawl sample file or acoustic scrutinized data). More commonly, the input data comes from another function executed at an earlier stage of the calculation. As a result of its processing, a function will produce intermediate output data and store it in memory. These data may also be written to file.

Parameters read from a “process file” will determine the execution behaviour and thus the calculations performed by a function. As an example, a trawl data filter function may have a parameter telling which species data to extract from the input data. The function parameter values of the process file are set by the user prior to execution of the model. Setting parameter values may be done programmatically from an external program, by editing the process file using an ASCII editor or through the StoX graphical user interface.

Predefined template models for standardized index calculations exist as a part of the StoX installation. The process file of these templates tells which functions to use and their order of execution. All the parameters are however initially blank or have a default value and needs to be edited by the user before execution.

During execution of a model, some function will update the process file with additional information. This is done so that the process file after execution will contain a complete

documentation on how a specific index was achieved. Based on this, it is possible to reproduce an index through a re-run, assuming you have access to the original input data and a copy of the process file made during the original execution.

Function library

StoX has a library of functions. Some index calculations may be done using different methods. For this reason, the library may contain several functions with similar purpose, but using different methods to achieve the same goal. Assignment and weighting of trawl data to acoustic NASC values during acoustic estimation can be used as an example. In one model it may be desirable to assign all trawl stations within a radius of the acoustic recording to the NASC value. Distances may be used to weight the different trawl stations. A special auto assignment function performs this task. In another model one may want to assign all trawl stations within the boundaries of a stratum to the NASC values of the same stratum. A third possibility is to assign trawl stations manually. Different function performs the assignment tasks in these cases.

One specific function may also be used in several different models / index calculations. Whether the user wants to perform swept area or acoustic estimation there is in both cases a need to read external trawl data. The function “read trawl data files” is used in both models.

High resolution calculation

One of the main conceptual ideas in StoX is to perform calculations at as high resolution as possible. Data are not aggregated to coarser resolution during the calculation until it is necessary. Using acoustic index calculation as an example, this implies that densities by length distribution are calculated for each NASC value of the original input acoustic dataset. In other words, for each channel of each integrator distance in the original data set.

There are several reasons for this approach:

- Bootstrapping techniques can more easily be applied
- Common functions can be used for different methods (e.g. calculation using transects vs. rectangles as the primary sampling unit (PSU)). There is consequently no need for developing special functions for each method.
- Depth dependent TS – length relationship can be applied

The high resolution approach gives flexibility for future development of new estimation methods and approaches.

Error handling

Due to the flexibility and variety of calculations StoX can perform, it is not possible to totally prevent incorrect use or faulty results. Incorrect user defined models or illogic parameter values may be used. In most cases this will lead to error messages and execution

stop, but StoX may also execute without warnings. The end user is responsible for using this tool properly, especially when running self-defined models.

Facilitating bootstrapping, time series analysis and statistical demands

When a model is setup and external data is present, it is the parameter values of the functions that determine the results of the calculations. As described above, the content of the process file can be altered in different ways. In many cases it is desirable and even vital to generate more than a straightforward index. Producing statistics on precision, uncertainty and so forth, is often required. This implies running parts of the calculation several times using different parameter values. The parameters may be picked randomly from within a range. To use such techniques, the StoX normally has to run in batch mode or be controlled from external software instead of a stepwise execution through the user interface.

The simplest form of multiple runs is the study of one parameters effect on the index. An example is acoustic index calculation with and without depth dependent TS-length relationship.

Bootstrapping techniques may be used on assigned trawl data or acoustic recordings.

To rerun a survey time series can be useful for different reasons. New knowledge on trawl selectivity or updated TS equations are examples of scenarios, which calls for a rerun of a time series.

Data interface and storage

Input data

The input data to StoX is typically trawl samples and scrutinized acoustic data by species group. These data may exist as files or being contained in a database. The various institutes and nations often use their own self-defined formats, but some exchange formats do exist. The StoX function library can easily be expanded with new “reader functions” as the demand emerges.

Tagged input data

When performing estimates using transect as the PSU, the observations belonging to a specific transect has to be tagged. Correct, automatic tagging of the data is not feasible. At IMR, new data can be tagged during the cruise and the tag is a variable in the data set. StoX can use this information.

For historic data or data from other sources, tagging information must be provided through a file or be performed in the StoX GIS window of the user interface.

Other types of tags than transect tagging may also be used by StoX. An example is tags to exclude survey data which should not be a part of the index calculation.

Intermediate data

Each function of the model produces intermediate output data, which by default are stored in memory. These data forms the input data to subsequent functions. Optionally, the intermediate data can be output to .csv or other file formats.

StoX can be run from external software like R. It is also possible to request intermediate data in R-formats through the R interface.

Access to intermediate data is useful for several reasons:

- To check the different steps of the calculation
- To facilitate own analysis beyond the standard index results
- Forms the basis for many of the default StoX reports
- To facilitate creation of new or external user defined reports

The intermediate data gives the user detailed and flexible access to data processed in a quality controlled software beyond an otherwise limited number of default reports.

Reports

A set of standard report programs will be located in a StoX repository. The reports are derived from the intermediate data. The report capability can easily be expanded. Report programs can be coded in any programming language as the intermediate data is available in standard file formats. Many reports will be in tabular form or as plots and graphs. A special type of reports is the ones presented in maps. The StoX geographical information system (GIS) window of the user interface is used to populate these reports. Map reports can be stored to file or printed.

Storage of estimates

Permanent storage of official estimates is not a part of the StoX infrastructure. Each institute using StoX has to handle this within their own data management structure. The following data must be considered for long term storage of an official estimate:

- The “process file” containing all information on how the estimate was achieved
- The standard reports giving the results of the index calculation
- The current version of the external input data (e.g. trawl sample data, acoustic data).
- If these data is later updated and a new version exists in the central storage, a rerun of the estimate on these data will give a different result than the initial run.

Sharing estimates

If several parties have access to the same external input data, an exchange of the process file is all that is needed to duplicate an estimate, including all intermediate data sets. Sharing reports is a less detailed way of exchanging index results.

User-interfaces and internal/external execution

The StoX application supports several types of user interfaces for execution of an index calculation. The different options have pros and cons as described below:

Graphical User Interface (GUI)

The GUI as shown in Figure 2, provides an easy and clear overview and control of the estimation setup and execution. Different panels is used to select the desired model (estimation method), show the functions used in the model and to set the parameter values for each function. A GIS window is used to display data and results, and to perform manual interactive actions on the data in a map.

The advantage of the GUI execution approach is a good overview of the estimation process and the manual data manipulation capabilities. The disadvantage is that time series analysis and bootstrapping is a slow and work intensive process.

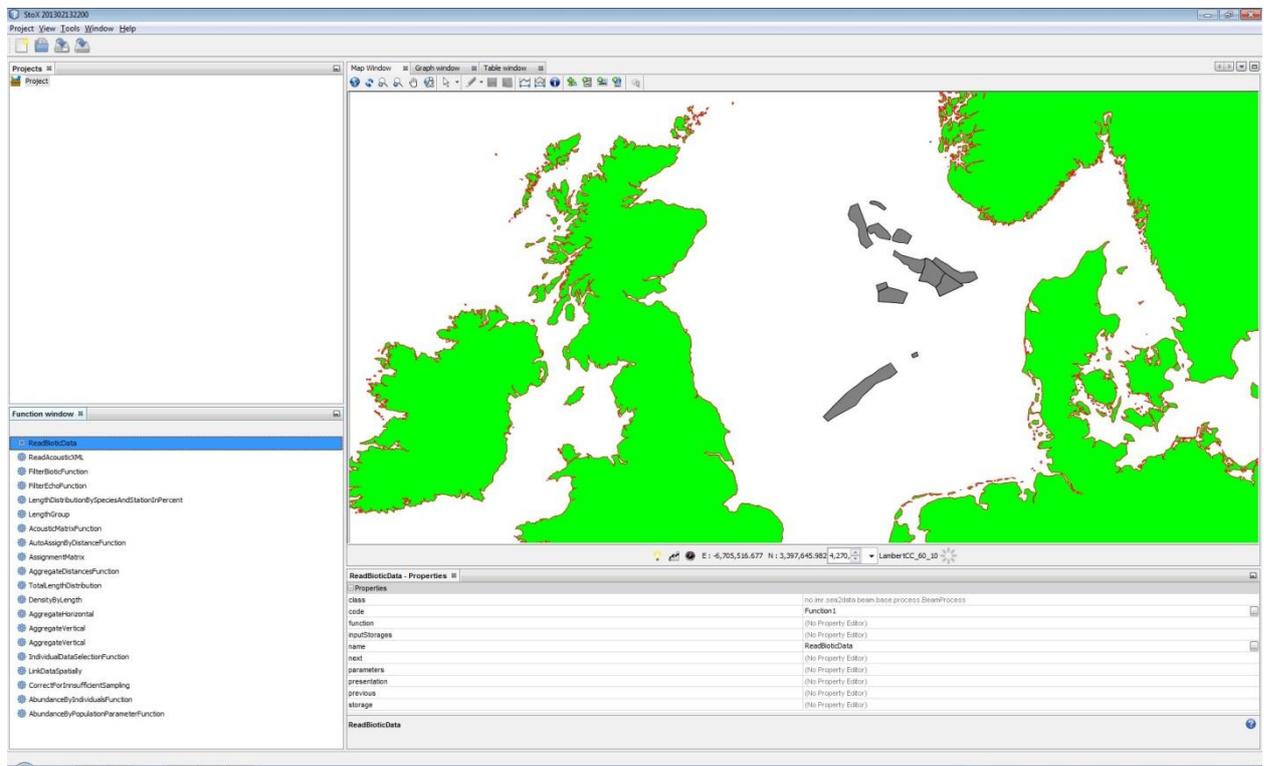


Figure 2. The StoX graphical user interface with interactive GIS. Model, function and parameter handling is facilitated together with execution control and reporting.

Java batch

The Java batch approach requires that no manual data manipulation is needed (e.g. manual assignment of trawl stations to acoustic values). The user only needs to edit the process file in an ASCII editor and execute the batch file.

The process file is a recipe for the desired model, describing which functions to use and their parameters.

R interface

This approach requires that no data needs to be manually manipulated. Through R, the user can execute StoX in much the same manner as by using Java batch method. It is however a much more flexible approach as the R user may write code to alter the content of the process file. This will again provide the user with the capability of running time series analysis, bootstrapping and studying the effects of different parameter settings (e.g. study effect of different trawl selection curves).

It is important to note that all intermediate data created by the various functions of the model may be written to files. This gives the scientist the possibility to perform self defined analysis which is not a part of StoX

Development software

Open source approach

The StoX application is entirely developed using open source software. This has several advantages:

- No license costs
- A large international community which continuously improve, update and document the development software on Internet
- Makes it easy to establish cooperation with other research institutes on the further improvement and expansion of StoX as a platform for survey calculations.

Open source components

The development software components of StoX are:

- Java which forms the basis for the application. All the coding done within the project is done in Java. In addition, the other external software components like GIS and Netbeans platform is also originally developed using Java.
- One of the panels of the GUI applications is a GIS window. The library is the open source Geotoolkit package which follows the OpenGIS consortium standards. It is used to develop a specialized GIS solution serving the purposes required by StoX.
- Netbeans platform is used as the environment to create a specially designed StoX GUI solution. Although the development environment is IDE independent.

Documentation

Software developer documentation

The StoX Java code is well documented to make it easier for external (outside IMR) and future programmers to maintain and expand the StoX code. Javadoc is implemented in all the Java classes of the application.

User documentation

- Each function in the library will have a user documentation. From the StoX graphical user interface, it is possible to select a function online and open the documentation. Alternatively, the same documentation is available as part of a documentation file.

- The document contains the following sections:
- Name of function
- Created, updated time stamp
- Input data demands and description
- Input parameter demands and description
- Output data description
- Purpose and functionality
- Calculations, formulas
- Example of functionality and/or calculations

Set up new mode vs standard models

User defined versus standardized models

Predefined models are used when a standardized calculation is to be performed. These models are quality controlled both with regards to software performance and scientific demands for proper and well published methodology.

It is however possible to set up user defined models to experiment and test ones own hypothesis. Used as an experimental tool, StoX cannot give any guarantee of adequate results. It is possible to set up models which is not logical and will result in error messages and termination of the program. To set up a user defined model, the process file has to be created with a listing of functions and their order of execution. The graphical user interface supports the creation of a user defines model, but it can also be done manually through a text editor.

Creating user defined models is an option for the advanced user.

Discussion

The motivation for making StoX was threefold. At IMR, several “home-brewed” programs have been applied to produce stock size indices, some of these have existed in parallel, and it has been up to the various cruise leaders to choose a preferred program in each case. Some of these programs, like for instance “Beam”, for making acoustic stock size estimates, were quality assured and designed to produce output that were well documented (Totland and Godø, 2001). Others were however more ad hoc and it was difficult to reproduce the same result if runs were repeated. The Barents Sea capelin stock is the only stock where the same well documented method has been applied during the whole time series of surveys. However, also in this case the implementation of the method has varied through the years. For other stocks, the methods have changed and are in some cases

poorly documented. This situation is far from ideal and was a major driver for the development of StoX.

Another motivation was the need for a more “open” method. For instance “Beam” has been criticized for being a “black box”, nearly impossible to look into if one did not have the licensed model builder used to construct the program (SAS) (Totland and Godø, 2001). This made sharing with other institutions as well as sharing across different departments at IMR more difficult. StoX is designed to overcome these problems, since the building blocks are open and the program itself will be treated as shareware.

The third and possibly most important motivation for making StoX was the need for a possibility to include new methods and further develop the methods for stock index calculations. Some researchers prefer transect based over traditional area-based estimation. The possibility to do bootstrapping of the various steps of the calculations has been asked for. New demands are put on stock assessment and for instance the possibility to present results with confidence limits is a prerequisite when developing new methods and applications. Those researches at IMR more engaged in methodical development than in routine surveying and stock assessment have also expressed a need for having a toolbox where alternative approaches could be tested and compared. It has been known for several years that some species have a depth-dependent target strength, and a program that can utilize such information is highly needed. Further, a program that can utilize density information either from acoustics, from trawl, or from other kinds of sampling gears and calculate indices within a common framework is also highly desirable. The possibility to have a common program taking all these wishes and needs into account triggered the making of StoX.

Acknowledgements

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2.5 Uncertainty properties of the Barents Sea capelin abundance estimate

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Management of Barents Sea capelin relies on one trawl-acoustic survey in September, which together with a 6 month stochastic simulation model and the harvest rule yields the quota. The rule dictates that there should be a maximum of 5% probability for the spawning stock biomass to be smaller than 200 000 tonnes and thus the uncertainty in the survey has a large influence on the catch quota. We investigate how the uncertainty in the survey depends on coverage by constructing a stochastic model for the capelin distribution that has the same large scale and small scale characteristics as seen from survey echograms. Based on repeated realisations of the capelin distribution the uncertainty of the survey is estimated for different degrees of coverage using the same square-based calculation scheme that is used on the survey. This is compared to calculations based on a transect method.

2.6 Uncertainties in calculations of consumption by Barents Sea cod

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Abstract

From 1984 onwards, cod stomachs from the Barents Sea have been sampled annually by IMR (Norway) and PINRO (Russia). A joint stomach content data base has been built up, and a large number of publications have been written. The cod stock's annual food consumption is calculated based on stomach samples and an evacuation rate model, and these consumption calculations are utilized in the assessment of Barents Sea capelin and Northeast Arctic cod and haddock. This paper discusses the methodological challenges and sources of uncertainty in stomach analysis and consumption calculations.

Introduction

From 1984 onwards, on average about 9000 cod (*Gadus morhua*) stomachs from the Barents Sea have been sampled annually and analyzed quantitatively by IMR (Norway) and PINRO (Russia), and a large number of publications have been written based on these data (see overview in Dolgov et al. 2007). Calculation of the prey consumption by predators is one of the main usages of stomach data. The first such calculations of prey consumption by Northeast Arctic cod consumption based on the joint IMR-PINRO stomach content data base were made by Mehl (1989), and since then a number of papers have been written on this issue. The diet of cod and other piscivorous fish in the Barents Sea is described by Dolgov et al. (2011).

Consumption calculation methods

The prey consumption by a predator stock depends on three factors: Observations of stomach content, stomach evacuation rate model and predator abundance.

The Northeast Arctic cod stock's consumption in tonnes of prey species i and prey size group j in season l ($C_{i,j,l}$) is calculated by

$$C_{i,j,l} = \sum R_{i,j,k,l,n} \cdot N_{l,n} \cdot P_{k,l,n} \cdot \text{const} \quad (\text{eq. 1})$$

where $R_{i,j,k,l,n}$ is the ration (g/hour) of prey species i and prey size group j in area k and season l for cod age group n , $N_{l,n}$ is the number of individuals (millions) of predator age group n in season l and $P_{k,l,n}$ is the proportion of individuals of predator age group n in season l which are found in area k . Const is a scaling factor in order to get the consumption in tonnes per season.

In the aggregation of data and further calculations the Barents Sea has in the Norwegian calculations (Bogstad and Mehl 1997) been divided into three main areas (Fig. 1) and the year has been divided in two seasons (first and second half of year). The main areas are based on the Norwegian demersal fish survey in winter (Jakobsen et al. 1997) combining two or three of those areas. This gives a 'natural' division of the Barents Sea in one northern and two southern parts, which to a certain degree reflects the changes in geographical distribution of both biotic and abiotic components of the ecosystem. The Russian calculations use only one area, but divide the year into quarters.

The stomach content data used in the calculations were collected onboard Norwegian and Russian research vessels during routine surveys in the Barents Sea, as well as on Russian commercial fishing vessels. Details about stomach sampling, analysis and aggregation of data are given in Mehl (1989) and Mehl and Yaragina (1992). The consumption is calculated for age groups 1-11+ separately, but the stomach content data have been pooled for the oldest age groups (7+/9+, depending on number of stomachs sampled). The following prey categories have been used: Amphipods (mainly Hyperiididae), krill (Euphausiacea), deep-water shrimp (*Pandalus borealis*), capelin (*Mallotus villosus*), herring (*Clupea harengus*), polar cod (*Boreogadus saida*), cod, haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes* spp.), Greenland halibut (*Reinhardtius hippoglossoides*), blue whiting (*Micromestitius poutassou*), long rough dab (*Hippoglossoides platessoides*) and other food. For prey < 30 cm, the consumption has been calculated for each 5 cm prey length group, while for prey > 30 cm, 10 cm length groups have been used.

The model used to estimate the food consumption of cod is based upon a function describing the gastric evacuation of different prey. dos Santos and Jobling (1995) give the following equation ('restricted' form):

$$S_t = S_0 2^{\frac{t}{\alpha_i S_0^\beta e^{-\gamma T} W^{-\delta}}} \quad (\text{eq. 2})$$

where S_t is stomach content at time t , S_0 is initial meal size (g), T is ambient temperature ($^{\circ}\text{C}$), W is body weight (g) and α_i is a prey-specific half-life constant, which has the following values for the prey species considered in this paper: Herring 88, polar cod 59, capelin 58, krill and amphipods 41, redfish, Greenland halibut and long rough dab 68¹, shrimp 103, haddock, cod and blue whiting 84, other food 58. $\beta=0.52$, $\delta=0.26$, $\gamma=0.13$.

If one assumes that over a period of days or weeks the fish reaches a steady state, i.e. the amount ingested equals the amount evacuated, the consumption (ration in g) of species i per hour, R_i , is given by:

$$R_i = \frac{\ln 2 e^{\gamma T} W^\delta S_i}{\alpha_i S_0^\beta} \quad (\text{eq. 3})$$

Another problem arises here since the initial meal size S_0 is normally not known in field work. As a further simplification, S_0 may be approximated by kS , where k is a constant factor. dos Santos and Jobling (1995) have also conducted experiments where the consumption model has been tested by feeding the cod for a two-week period, and comparing the consumption calculated using the above equation to the observed consumption. When this is done, and the calculations are made based on pooled stomachs, the consumption is overestimated by 35%. In order to get the correct estimate, k must then be set to 1.78.

The temperature is calculated using climatological data for representative positions in each area (Ottersen and Ådlandsvik 1993) adjusted by the yearly variation in the Kola section (Tereshchenko 1996).

The number and individual weight in each age group in the Northeast Arctic cod stock by season and year is based on Virtual Population Analysis (VPA) data from the ICES Arctic Fisheries Working Group. For the different seasons, the number and weight in the middle of the season (1 April and 1 October) is used. The allocation of individuals of each age group by area and season in the different years is based on acoustic and bottom trawl data from Norwegian surveys on demersal fish in January-March and August-September). It is assumed that the spawning component is outside the Barents Sea for three months during the first half of the year, and this component is not included when the cod stock's consumption is calculated.

¹ While writing this article, it was found that dos Santos and Jobling did experiments with long rough dab as prey, so in future calculations the long rough dab value (62) will be used for long rough dab and Greenland halibut.

Use of consumption data in stock assessments

Predation by cod is already included in the stock assessment of Northeast Arctic cod and haddock and Barents Sea capelin (ICES 2013). This could be extended to include predation by cod on herring and *Sebastes mentella* also. The biomass consumed calculated from eq. 1 is converted to number consumed by prey length group using a length-weight relationship from surveys. For cod, haddock and herring, also age-length keys for the prey are necessary since the models used are age-distributed. Such age-length keys also have to be based on survey data, as the age of the prey is not recorded when stomach content analyses are performed. For capelin and *S. mentella*, data on length distributions should be sufficient. For capelin it is very important with length distributions in order to determine whether the predation by cod takes place on immature or mature capelin (< 14cm).

It is also important to compare the calculated consumption with the observed growth rate of the predator, to see if these are compatible. Such comparisons were done for Northeast Arctic cod by Bogstad and Mehl (1997), and they found them generally to be compatible, with food conversion efficiencies mostly in the 10-20 % range.

Sources of uncertainty

4.1 Stomach content data

There are differences in which season the data are sampled in – Norwegian data are mainly sampled on surveys in Q1 and Q3 while Russian data are sampled on surveys in Q3 and Q4 and also from commercial vessels in all quarters. Thus, the poorest coverage is in the second quarter. Maps showing the annual sampling of stomach content data are given in Dolgov et al. (2007). The spatial variations in stomach content are shown e.g. in Mehl et al. (2013) for the winter survey for the period 2007-2012, and in Anon. 2006, 2008 for the ecosystem surveys in 2005, 2006, 2007.

It would of course also be preferable to be able to calculate the consumption by mature cod during the period when it is outside the Barents Sea. This is particularly important when the mature stock is a large proportion of the total stock, as is currently the case. Until 2006, the diet of cod was also investigated during the Lofoten survey, when the cod mainly feeds on herring (Michalsen et al. 2008). However, stomach sampling on the Lofoten survey has been discontinued.

The sampling strategy has changed throughout the period 1984-present. For the winter survey, the stomach sampling is stratified by length, and the number of stomach analysed per 5 cm length group has been reduced from 5 to 2 to 1 (from 1996 onwards – Jakobsen et al. 1997). However, the number of stations where stomachs are sampled has been increased considerably, as stomach samples are now taken at all stations. This change to sampling more stations, but fewer stomachs at each station has been shown to improve the precision in calculation of average stomach content in the population (Bogstad et al. 1995). In the ecosystem survey, the same strategy as in the winter survey is used. The sampling procedures on Russian commercial vessels and Russian national research surveys is

different, usually 25 stomachs are analysed from each trawl station using random sampling.

It can be questioned whether the stomach content in the fish which are sampled, is representative for the fish present in the area. Both the vertical distribution of fish, feeding in the trawl, regurgitation and behavior relative to the trawl could cause a bias. Of these factors, the vertical distribution is probably the most important. We have limited knowledge of this, as we have few samples of cod from pelagic trawl hauls (but see Ajiad 1990), and also the vertical migrations of cod are not well known. However, we know that cod feed on capelin and also other prey items which generally are distributed higher up in the water column than the cod is.

Table 1 and 2 shows the proportion of the stomach content which is determined to various levels, for Norwegian and Russian data, respectively. These proportions are calculated annually for the period 2003-2012, based on aggregated data for all cod size groups.

For both countries we see that the proportion of totally indeterminate prey is very small (< 1%). The proportion of fish in the diet is higher in the Norwegian than the Russian data because differences in which season the data are sampled in – Norwegian data are mainly sampled on surveys in Q1 and Q3 while Russian data are sampled on surveys in Q3 and Q4 and also from commercial vessels. Also, data from Russian commercial vessels and most of the data from scientific surveys are analysed on board the vessel, which naturally leads to a somewhat lower level of prey identification and size determination. Maps showing the annual sampling of stomach content data are given in Dolgov et al. (2007). In most years, the diet in Q1 is dominated by capelin.

Overall, the determination level of fish prey seems to be higher in the Norwegian data than in the Russian data (28 vs. 17 % of total fish prey weight is completely determined). The difference is smaller for capelin (17 vs. 13%). It is, however, noteworthy that the majority of fish prey is only partially determined.

The weight of each prey species and size group was adjusted by redistributing the unidentified components of the diet among the various identified components, taking into account the level of identification. If the consumption is calculated on basis of individual stomachs, it is needed to use stomachs sampled at stations in the same area or time period in order to do the redistribution. If the weight and number of prey is recorded, this contains some information about the possible prey length range, and such information could be utilized in the redistribution.

Although the stomach evacuation rate is dependent on prey species, we do not account for that the identifiability of the prey may depend on species and size, and this may cause a bias when the indeterminate or partly determined stomach content is re-distributed as described above.

Before 1993, the prey length was recorded using wide length groups (5-6.9 cm, 7-9.9 cm, 10-14.9 cm, 15-19.9 cm, 20-24.9 cm, 25-29.9 cm, 30-39.9 cm, 40-49.9 cm were the groups

used in the length range where most fish prey are found). These wide length groups certainly introduce additional uncertainty in the prey length, in particular, the length groups were unsuitable for distinguishing between immature and mature capelin (maturation length about 14.0 cm). However, when the change to 1 cm length groups for this prey length range was made, it may have caused that fewer prey were actually measured because they could not be measured to the nearest cm.

For the time being the same age-length keys and weight-length relationships are used in all 3 areas when converting the number of cod and haddock. This may cause some bias in the calculations of number by age consumed, as there are spatial differences in length and weight at age (Mehl et al. 2013).

The parameters in equations 2 and 3 are given with uncertainty in dos Santos and Jobling (1995), for capelin, herring, redfish, long rough dab, haddock, polar cod, krill, shrimp, squid and Arenicola (a polychaete) as prey. Meal size is not known in the field, so Temming and Andersen (1994) fitted a model without meal size to the same data, which gave almost as good a fit. However, this was only done for capelin, herring and shrimp as prey, which is one of the reasons why the Temming and Andersen model has not been utilized in the annual consumption calculations. Another source of uncertainty is the choice of evacuation rate model for prey items for which no experiments have been made.

Using a single temperature value an area and season is also a source of uncertainty, as the temperature variability within an area (horizontally as well as vertically) and season is fairly large.

The total abundance of the predator is calculated from a stock estimate (e.g. VPA), and suffers from the usual uncertainties associated with such estimates (natural mortality, uncertainty in catch at age, convergence of VPA making the estimates for the last years more uncertain than for earlier years etc.). Also, cod cannibalism is included in the VPA for cod using an iterative procedure (ICES 2013), so that the amount of cod in cod stomachs also affects the calculated abundance and thus consumption of the younger age groups of cod. Most of the predation by cod on younger cod is on ages 1-3, but also predation on ages 4-6 is included in the calculation. It is assumed that natural mortality $M=0.2$ +cannibalism mortality.

The calculations will be considerably affected by the choice of spatial and temporal scale. Since the consumption is a non-linear function of stomach content, and the temperature is variable within an area and time period, using average stomach content in the calculations also creates a bias compared with calculations based on individual stomachs.

From a single survey one could calculate a predator abundance-weighted estimate of consumption during the survey period based on individual stomach content data and temperature data for each station, using the same approach as for calculating bottom trawl swept area estimates (e. g. Jakobsen et al. 1997). Such an approach was taken by

Tjelmeland (2005) when calculating consumption of capelin by cod for use in the parameterization a multispecies model. In that paper, the uncertainty was represented by making replicates.

Software for such calculations have so far not been included in the standard computer programs used for making bottom trawl estimates at IMR, but this will be included in the new Sea2Data data base and data handling system, which is under development. However, the redistribution of indeterminate or partly determined stomach content can not be based on data from other stomachs from the same stations; data from a larger area has to be used, in a similar way to the approach taken with age-length keys.

There is a fundamental difference between calculating survey estimate and calculating consumption estimate. The survey estimate is a measure of the stock abundance at a given point in time – provided that one can ignore the effect of migration during the survey and that the mortality during the survey is small. The calculated consumption is an estimate of the consumption during a time period, where normally there is not sampling going on for the whole period and thus assumptions have to be made about how to extrapolate in time. This also makes uncertainty estimates much more difficult for consumption calculations.

It is not straightforward how to combine the data – and how to calculate uncertainty - when several surveys with different catchability, as well as data from commercial fisheries, are available for a given time period. So far unweighted averages of stomach content for each period and area have been used in the consumption calculations, a simplistic approach which gives too much weight to stomachs sampled at stations with low cod abundance

5 Conclusions

There are a lot of uncertainties and possible biases in consumption calculations, some of which are hard to quantify. The methodology used for calculating the prey consumption by Barents Sea cod should be improved to avoid biases and quantify uncertainties as far as possible.

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Year	% indeterminate prey	% fish in diet	% of diet which is indeterminate fish	% of diet which is partly determined (species/genus but not size)	% of diet which is fish determined to species and size	% of diet which is length determined capelin	% of diet which is capelin without determined length
2003	0.09	88.71	8.75	59.54	20.42	8.26	44.14
2004	0.13	81.41	19.03	38.97	23.41	4.45	18.24
2005	0.38	85.25	14.11	35.07	36.07	5.49	9.83
2006	0.16	88.64	11.68	45.04	31.92	6.40	25.72
2007	0.09	81.75	8.24	40.34	33.17	5.06	18.95
2008	0.07	89.76	12.18	59.21	18.37	5.44	47.34
2009	0.04	84.18	10.30	49.75	24.13	8.70	31.03
2010	0.14	90.72	11.95	61.87	16.90	8.91	47.51
2011	0.08	87.43	21.63	54.56	11.24	4.85	45.61
2012	0.12	85.51	15.37	45.79	24.35	10.85	34.48
Average	0.13	86.34	13.32	49.01	24.00	6.84	32.29

Table 1. Percentage of cod stomach content determined to various levels. Norwegian data, aggregated over all size groups.

Year	% indeterminate prey	% fish in diet	% of diet which is indeterminate fish	% of diet which is partly determined (species/genus but not size)	% of diet which is fish determined to species and size	% of diet which is length determined capelin	% of diet which is capelin without determined length
2003	0.36	77.33	19.8	54.24	3.29	0.81	11.87
2004	0.81	67.41	12.75	43.57	11.09	2.02	17.02
2005	0.44	74.95	14.82	55.24	4.89	0.74	10.43
2006	0.09	73.45	8.04	57.27	8.14	2.76	19.37
2007	0.07	71.99	8.71	50.85	12.43	2.28	16.02
2008	0.13	75.85	9.54	47.29	19.02	4.02	14.6
2009	0.46	69.47	9.61	51.2	8.66	1.56	18.77
2010	0.37	69.97	4.14	50.74	15.09	2.64	22.04
2011	0.16	70.77	6.43	41.20	23.14	5.11	18.96
2012	0.20	62.55	8.86	36.98	16.71	2.18	11.06
Average	0.31	71.37	10.27	48.86	12.25	2.41	16.01

Table 2. Percentage of cod stomach content determined to various levels. Russian data, aggregated over all size groups.

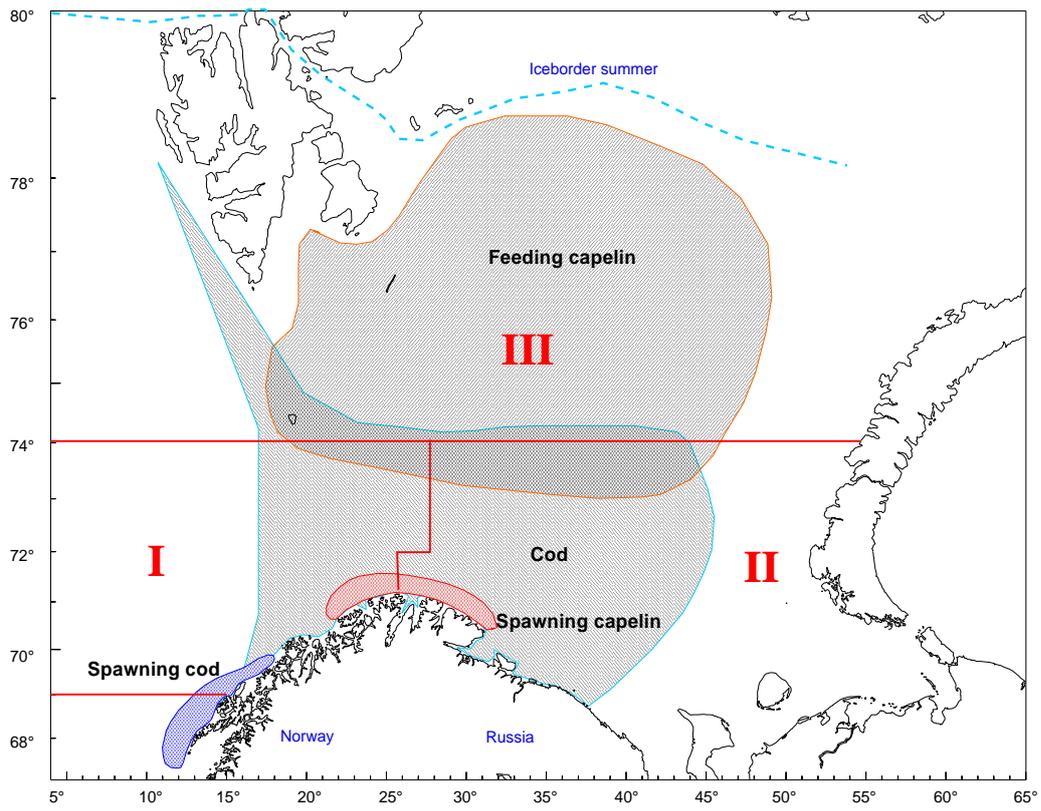


Figure 1. Area division used in Norwegian consumption calculations.

2.7 Results from the research on the hydroacoustic target strength of the main commercial fishes in situ in the Barents and Norwegian seas.

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Acoustic target strength TS and its dependence on length L (TS-L dependence) for fish different species in situ are key in the assessments of fish stocks by hydroacoustics. The TS-L dependences to be used, which are based on a small number of TS measurements, made 30-35 years ago, need checking and adjusting. This paper presents methods and results of estimating TS and TS-L relationships in 2000-2012. The methods are based on the use of Simrad EK60 scientific echo sounder with precision TVG, offsetting the loss of sound waves with depth, and the split-beam transducers that measure TS, research pelagic (2492 and A8-623) and bottom (Campelen- 1800 and 2283-02) trawls and Simrad BI60 and Famas (TINRO) software for collection, storage and postprocessing of the acoustic data obtained during the trawl-acoustic surveys (TAS) to assess fish stocks. Here are presented the following TS-L dependences of the main commercial fish species, which have been identified on the basis of a meta-analysis of the data on TS, on a frequency of 38 kHz, in order to improve the accuracy of the assessment of the fish stocks in the Barents and Norwegian Seas by the TAS-method:

$$\text{TS(Cod, L=5-50 cm)} = 21.6 \lg L - 69.2; r^2=0.98; \text{ s.e.}=1.1; n=90, \quad (1)$$

$$\text{TS(Cod, L=50-100 cm)} = 25.0 \lg L - 74.5; r^2=0.81; \text{ s.e.}=1.1; n=402, \quad (2)$$

$$\text{TS(Cod, L=100-145 cm)} = 36.8 \lg L - 97.6; r^2=0.78; \text{ s.e.}=1.0; n=315, \quad (3)$$

$$\text{TS(Cod, L=50-145 cm)} = 28.5 \lg L - 81.0; r^2=0.89; \text{ s.e.}=1.1; n=633, \quad (4)$$

$$\text{TS(Cod, L=5-145 cm)} = 24.9 \lg L - 73.8; r^2=0.96; \text{ s.e.}=1.3; n=702, \quad (5)$$

$$\text{TS(Haddock, L=8-81 cm)} = 21.9 \lg L - 69.5; r^2=0.87; \text{ s.e.}=1.3; n=195, \quad (6)$$

$$\text{TS(Polar cod, L=3,5-29 cm)} = 18.3 \lg L - 68.2; r^2=0.97; \text{ s.e.}=0.9; n=176, \quad (7)$$

$$\text{TS(Capelin, L=3,2-18 cm)} = 19.0 \lg L - 73.8; r^2=0.95; \text{ s.e.}=1.0; n=109, \quad (8)$$

$$\text{TS(Blue whiting, NS, L=18-44 cm)} = 27.8 \lg L - 75.3; r^2=0.92; \text{ s.e.}=0.8; n=61, \quad (9)$$

$$\text{TS(Saithe, L=8-114 cm)} = 23.8 \lg L - 70.8; r^2=0.98; \text{ s.e.}=1.4; n=27, \quad (10)$$

$$\text{TS(BRF, BS, L=6-36 cm)} = 18.5 \lg L - 68.4; r^2=0.97; \text{ s.e.}=1.1; n=112, \quad (11)$$

$$\text{TS(BRF, BS, L=36-47 cm)} = 54.4 \lg L - 124.3; r^2=0.77; \text{ s.e.}=1.0; n=66, \quad (12)$$

where r^2 - reliability of approximation, s.e. - standard error, n-number of pairs of TS and L data, BRF-beaked redfish, BS-the Barents Sea, NS- the Norwegian Sea.

Theme session III: **Stock assessment methods**

3.1 A statistical assessment model applied on Northeast Arctic haddock.

Gjert E. Dingsør, Daniel Howell, and Knut Korsbrekke
Institute of Marine Research, Bergen, Norway

Both catch statistics and survey indices are strongly influenced by observation noise. Traditional, deterministic stock assessment models ignore the observation noise and give point estimates. Among several advantages, statistical stock assessment models; 1) do not assume observations without errors, 2) estimation of uncertainties are an integrated part of the model, 3) maximum likelihood estimation of model parameters, 4) allows selectivity to evolve, 5) handles missing values, and 6) prediction is straight forward. SAM is a state-space fish stock assessment model that have been applied on many stocks within the ICES expert groups, many of them are gadoid fish stocks. In this article we apply SAM on Northeast Arctic haddock and show some of the features of this assessment model.

3.2 Challenges in catch at age stock assessment models

Knut Korsbrekke and Gjert Endre Dingsør
Institute of Marine Research, Bergen, Norway

Traditional catch at age based stock assessment models are mainly based on the cohort equation and the catch equation (Baranov equation) with additional assumptions. The assumptions relate to the information used as input to the models and may influence how the catch equation is solved. The focus of this paper is the assumptions regarding natural mortality, exploitation pattern and catchability (how scientific survey indices relate to stock size) and it is shown how additional information can be used to increase the precision in stock assessment models by explaining how natural mortality, exploitation pattern and survey catchability vary over time. A particular focus is given to models of catchability and it is shown how parameters of a local process (trawl efficiency) can be estimated in a global stock assessment model. The use of additional information allows for a higher degree of complexity and realism in the assessment models, but is rather demanding on the number of observations needed to estimate parameters especially when estimates of survey indices and catch at age matrixes have low precision.

3.3 A retrospective evaluation of the Barents Sea capelin management advice

Harald Gjørseter, Bjarte Bogstad, Sigurd Tjelmeland & Samuel Subey
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Since 1998, the assessment model framework Bifrost/Captool has been used for advice on total allowable catch for the Barents Sea capelin (*Mallotus villosus*) stock. However, since the management is based on a target escapement strategy, and most capelin die after spawning, viewed in retrospect, there is hardly any possibility of checking whether the forecast underpinning the quota was actually realistic. The forecast using Captool for the period from 1 October up to capelin spawning time at 1 April relies on a forecast of cod abundance during this period. This estimate of cod abundance is, in turn, based on a cod assessment from the previous spring. By rerunning the Captool model, where the cod forecast is replaced with the actual amount of cod from the cod assessment model run later in time, we show that considerably smaller annual quotas would have been advised if the true amount of cod had been known when the capelin quota was set. We discuss this fact in light of the present knowledge about recruitment success of capelin during the period. Our conclusion is that either the acoustic stock size estimates of capelin have been consistently underestimating the true stock size, the predation model overestimates the natural mortality of capelin during winter, the minimum spawning stock size considered necessary to uphold normal recruitment (Blim) built into the harvest control rule is higher than needed to secure good recruitment, or a combination of these.

This paper is published in the journal Marine Biology Research:

Gjørseter, H., B. Bogstad, S. Tjelmeland and S. Subbey 2015. A retrospective evaluation of the Barents Sea capelin management advice. *Marine Biology Research*, 11: 135-143.

<http://dx.doi.org/10.1080/17451000.2014.928414>

3.4 Multispecies harvest rules for the Barents Sea.

Sigurd Tjelmeland, Harald Gjøsæter and Bjarte Bogstad
Institute of Marine Research, Bergen, Norway

The assessment model underlying the management of Barents Sea capelin is augmented with modelling the recruitment and used for long term stochastic simulation to test harvest rules. Capelin-cod interactions are endogenously modelled and the influence of herring on capelin recruitment is modelled as a term in the recruitment function. In order to minimize modelling error a large number of plausible recruitment functions for capelin using different covariates in addition to spawning stock biomass are estimated and the best are selected using the Akaike criterion. Optimal harvest rules for capelin are estimated conditional on harvest rules applied for herring and cod.

3.5 Modelling of population dynamics of red king crab in the Barents Sea.

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In the paper the analytical review of the principles to simulate red king crab population dynamics in the Barents Sea was made, as well as the alternative approaches to study population characteristics allowing for the input data amount were also considered. The first paper part has reviewed analytical models adapted to estimate the red king crab stock status in the Barents Sea.

To estimate stock and abundance dynamics used were a production model as well as two models based on the abundance dynamics of size groups, the Length-Based Analysis, LBA, consisting of 12 size groups and the Catch Survey Analysis, CSA, including 3 size groups. Besides, the Leslie depletion model has been analysed and the prospects to use it in the estimation of the Barents Sea crab population have been shown.

The second part of the paper studies methods to estimate the parameters of the above mentioned models. The Bayesian approach and the algorithm to use it in the abundance dynamics simulation have been described in details. It has been concluded about the expediency to apply this or that model type with regard for the input data quality and amount.

3.6 Evaluation of the NEA cod assessment quality.

Yury Kovalev and Anatoly Chetyrkin

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The North-East Arctic cod stock is currently assessed by the ICES AFWG using the VPA model with XSA tuning. In recent years, the XSA model has applied the same settings with only minor changes. Changes in model parameters and input data can affect the quality of the NEA cod stock assessment. The main objective of this work was to explore this impact in order to test and optimize current model parameters.

Based on the results of AFWG-2012 a number of alternative assessments were carried out with different data sets and model assumptions. A proposal was made to use the same survey set and age ranges in indices as those applied by AFWG-2012, to continue the use of FLR for assessment and maximize the number of iterations in XSA. It was recommended to continue using consumption data in assessment.

It was revealed that currently the NEA cod stock assessment becomes extremely sensitive to the parameter “Catchability dependent on stock size for ages” for ages older than 5. There is a need to check the impact of this parameter on the simulation results and XSA diagnostic on the annual basis to get the first signal from new data helping to choose its correct value. A possible optimal XSA parameters set was discussed.

3.7 Different maturity scales affect estimations of fecundity, TEP and spawning stock size of Greenland Halibut, *Reinhardtius hippoglossoides* (Walbaum 1792)

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Based on 138 samples from female Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum) taken in November-December 2011 at spawning grounds on the continental slope of the Barents Sea, the relationships between fecundity and fish size were established and found to be in the same range as those of estimations from 1996, 1997 and 1998. Ovarian maturity stages were determined by using a scale proposed by Kennedy et al. (2011) based on microscopic oocyte diameter measurements. These data were compared to the maturity stages determined at sea in a routine manner, based on a standard macroscopic scale and a macroscopic scale previously developed for Greenland halibut. Maturity ogives were derived based on the three different maturity scales and an overestimation of both spawning stock size and TEP of approximately 20% was found when the macroscopic scales were used in conventional way to derive maturity ogives.

Most accurate ogives are assumed to be derived based on the microscopic scale, but this method can be impractical at sea on routine surveys. Thus, it is proposed to use the special macroscopic scale for Greenland halibut females, but consider both truly immature (stage 1) and early maturing (stage 2) females as non-spawning. This adjustment gives maturity ogives that do not deviate significantly from the ones based on the microscopic scale, and results in estimates of spawning stock size and TEP that we consider appropriate for stock assessment purposes.

3.8 Methodological principles of entropy reduction in the assessment of «stock-catch» system

Yuri A. Kuznetsov and Artur A. Maiss

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The treatment of biological parameters with the usage of fishing analog is very useful for simplifying the algorithm of their interaction and collecting large amounts of fishing and biological information. But simplifications establish stability in engineering systems. Open organized complexity system approach is more reliable in biology. Entropy in terms of unstable “stock-catch” (SC) system condition and decision making uncertainties can be significantly reduced by applying instrumental methods of contemporary hydrobionics when estimating fish and fishing gear interaction in the local area of fishing system.

This report suggests adding biophysical content to the targeted bio-fishing parameters of the SC system. Bionical approach is optimized for reaching the preferendum of physical and technical factors’ scores affecting fishes’ selective reactions during the process of fish formation. The possibility of the efficient spatial-temporal modeling of biophysical process in critical areas of trawling system is demonstrated by the example of trawl-acoustic survey. Many variations in the fishery which traditionally were put in correspondence with one and the same probability in different situations can be subject to factor analysis.

Database structure for hydrocoles adaptation (perception, orientation, locomotion, species and age peculiarity), hydrophysical disturbances in trawling areas due to technical parameters of fishing complexes and their operating regimes is more suitable for fishing dynamics. That’s why adaptive and determinate exposition of fish trawling processes and updating of research and information unit of the fishing monitoring system (FMS) based on the appropriate method will expand FMS’s user community and provide decision-makers with unbiased information on current fishing state. It’s believed that its modernization will be effective for trying new engineering solutions, rules and guidelines for stock regulation under actual conditions of fishing area.

Appendix 1: Symposium programme

The 16th Russian-Norwegian Symposium on
Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology
Sochi, Russia, 10-12 September 2013

Organized by the Institute of Marine Research (IMR), Norway and Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia

Participation

The symposium addressed scientists, fishery managers and representatives of the fishing industry.

Scope

The main subject of the Symposium is assessment of commercial aquatic organisms in the Barents Sea which is essential to management and sustainable development of the Barents region economies. Thematic coverage is tailored for professionals in fisheries research and management, as well as industry.

Proceedings

Titles of presentations and abstracts not exceeding 300 words to be submitted to PINRO (kovalev@pinro.ru) and IMR (knut.sunnanaa@imr.no).

The Symposium proceedings will be published in the IMR/PINRO Joint Report Series. The Organizing Committee will select papers from the Symposium for publication in a peer-reviewed journal, preferably *Marine Biology Research* (MBR).

Organizing Committee

Russia:	Norway:
Evgeny Shamray (PINRO)	Harald Gjøsæter (IMR)
Yury Kovalev (PINRO)	Espen Johnsen (IMR)
Dimitry Vasiliev (VNIRO)	Knut Sunnanå (IMR)

Tuesday 10 September

09.00 – 09.40 Registration

09.40 – 10.00 Opening addresses
Knut Sunnanå (IMR, Norway)
Yury Lepesevich (PINRO, Russia)

10.00-10.30 **Theme session I:** Survey strategy and methodology
(Evgeny Shamray/Harald Gjøsæter)

Jon Helge Vølstad (IMR, Bergen, Norway):
Survey sampling of fish and fisheries - how much is enough? (Keynote)

10.30 – 11.00 Coffee break

11.00 – 13.00:

Shale Rosen, Melanie Underwood, Arill Engås (presenter) and Elena Eriksen (Norway):
DeepVision: an in-trawl stereo camera makes a step forward in monitoring the pelagic community.

Hein Rune Skjoldal, Elena Eriksen (presenter), Edda Johannesen (Norway), Dmitry Prozorkevich and Tatiana Prokhorova (Russia):
Ecosystem approach to management: assessing the state of the Barents Sea ecosystem.

E.Eriksen (presenter), H.Gjøsæter, K.Sunnanå, HR. Skjoldal, E.Johannesen, R.Wienerroither, J.H.Vølstad, B.Bogstad, L.Jørgensen (Norway) D.Prozorkevich, Ju. Kovalev, T.Prokhorova (Russia):
The Barents Sea survey strategy: the way forward to monitor the ecosystem.

E.L. Orlova, A.V. Dolgov (presenter), D.V.Prozorkevich, I.P. Prokopchuk (Russia), E.Eriksen, H.-R. Skjoldal (Norway):
The methodological challenges to evaluation of euphausiids stocks and their role in the Barents Sea ecosystem.

Tor Arne Øigård (presenter), Tore Haug and Kjell Tormod Nilssen (Norway):
Pup production survey with subsequent stock assessment of Harp Seals in the Greenland Sea.

Vladimir Zabavnikov (Russia):
Research of the White/Barents Seas Harp Seal Population on Whelping Patches with Use of Multispectral Air Surveys.

13.00 – 14.30 Lunch

14.30 16.30:

Michael Pennington (Norway, presented by Jon Helge Vølstad):

Evaluation of the sampling strategy for the Norwegian-Russian 0-group component of the ecosystem summer survey.

Krysov A.I. and Ignashkin V.A. (presenter) (Russia):

Development of the trawl-acoustic survey for blue whiting in the spawning grounds to the west of the British Isles.

M. Shevelev, O. Smirnov (presenter), A. Sokolov, Yu. Kovalev, A. Russkikh, P. Murashko and A. Amelkin (Russia):

History and evolution of the Russian Barents Sea autumn-winter multispecies trawl-acoustic survey.

Hallfredsson E. H. (presenter), Hallfredsson E. H., Jørgensen T. (Norway), Pavlenko A., Smirnov O. (Russia):

Sexual dimorphism in relation to technical measurements and gear selectivity in Greenland halibut trawl fisheries in the Barents Sea.

L. Buhl-Mortensen (Norway):

MAREANO, a national mapping programme documenting bottom topography, the environment and bottom fauna on the continental shelf and slope of Northern Norway.

16.30 – 17.30 Coffee & Poster session

19.30 The conference dinner

Wednesday 11 September

09.00 – 09.30 **Theme session II:** Index calculations
(Co-chairs Oleg Titov/Knut Sunnanå)

Paul Wassmann (Univ Tromsø, Norway): “The heritage after Nansen” (Keynote).

09.30-10.30:

Erling Kåre Stenevik, Jon Helge Vølstad (presenter), Åge Høines, and Sondre Aanes (Norway):

Uncertainty in estimates of density and biomass of Norwegian spring spawning herring based on combined acoustic and trawl surveys.

Knut Korsbrekke (Norway, presented by Espen Johnsen):
Probability based estimates of a demersal trawl survey.

Knut Korsbrekke, Gjert Endre Dingsør, Espen Johnsen (presenter, Norway):
Variance and estimates of number of individuals from acoustic surveys.

10.30-11.00 Coffee break

11.00-12.20:

Totland Atle, Gjøsæter Harald (Presenter), Handegard Nils Olav, Johnsen Espen and Lid Sjur Ringheim (Norway):

“S2D StoX” – standardized stock index calculations made easy.

Sigurd Tjelmeland, Harald Gjøsæter (presenter) and Samuel Subbey (Norway):
Uncertainty properties of the Barents Sea capelin abundance estimate.

Bjarte Bogstad (Norway):
Uncertainties in calculations of consumption by Barents Sea cod

13.00-14.30 Lunch

14.30-16.30 **Theme session III:** Stock assessment methods
(Co-chairs: Yury Kovalev/Yury Lepesevich/ Espen Johnsen)

Gjert E. Dingsør (presenter), Daniel Howell, and Knut Korsbrekke (Norway):
A statistical assessment model applied on Northeast Arctic haddock.

Knut Korsbrekke and Gjert Endre Dingsør (presenter, Norway):
Challenges in catch at age stock assessment models.

Harald Gjøsæter (presenter) and Bjarte Bogstad (Norway):
Performance of the Capelin assessment model Bifrost/CapTool.

Sigurd Tjelmeland (presenter), Harald Gjøsæter and Bjarte Bogstad (Norway):
Multispecies harvest rules for the Barents Sea.

Sergey Bakanev (Russia):

Modelling of population dynamics of commercial crabs in the Barents Sea.

Yury Kovalev and Anatoly Chetyrkin (presenter) (Russia): Evaluation of the NEA cod assessment quality.

Lara Nunez, Elvar Hallfredsson (presenter) and Inger-Britt Falk-Petersen (Norway):
Different maturity scales affect estimations of fecundity, TEP and spawning stock size of Greenland Halibut, *Reinhardtius hippoglossoides* (Walbaum 1792)

16.30 – 17.00 Coffee break

17.00 - 18.00 Discussion

Thursday 12 September

09.00 - 11.00 Discussion

14.00 – 19.00 Excursion

Posters

Theme session I: Survey strategy and methodology

Åge Høines, Edda Johannesen, Thomas de Lange Wenneck (Norway): The Barents Sea ecosystem survey: fish assemblages in the Svalbard sub-area.

D. Prozorkevich (PINRO, Russia) and E. Eriksen (Norway): Significance of cod settlement on 0-group cod abundance indices, and how to reduce this.

Theme session II: Index calculations

Nils Olav Handegard, Harald Gjøsæter, Geir Odd Johansen, Jens Otto Krakstad, Sjur Ringheim Lid, Helge Sagen, Trond Westgård and Geir Huse (Norway):
Efficient infrastructure in support of fisheries management – lessons learned at IMR.

Ermolchev V.A., Astakhov A.Yu., Zubov V.I., Ignashkin V.A., Lyutiy S.G., Nosov M.A., Sergeeva T.M., Harlin S.N. (Russia):

Research results of hydroacoustic target strength of main commercial fish in situ in the Barents and Norwegian seas.

Theme session III: Management implications and challenges.

Yuri A. Kuznetsov, Artur A. Maiss (Russia):

Methodological principles of entropy reduction in the assessment of «stock-catch» system.

Appendix 2: List of participants

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