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A monitoring strategy for the Barents Sea

Report from project nr.14256 Survey strategy for the Barents Sea

Edited by Elena Eriksen and Harald Gjøsæter

Photo: B. Isaksen

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HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

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Edited by Elena Eriksen and Harald Gjøsæter

Foto: Erik Olsen

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Executive summary

The present report is partly the results of work at IMR, partly of discussions with our main cooperative institute, PINRO. While some of the recommendations are definite, work is still ongoing regarding how the present monitoring system should be further developed to secure a timely and effective monitoring of the Barents Sea ecosystem in the various seasons. This work cannot be done by one of the cooperating institutes alone, but further discussion regarding how the present four surveys during autumn-winter could be combined into two joint surveys will take place during January 2014.

During the history of monitoring the Barents Sea ecosystem, various surveys have been conducted, mainly 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.

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) estimate the cost. The long term plans should secure increased competence and continuation of expertise for involved leaders, scientists, technicians and users.

Disadvantages with the present monitoring:

- ✓ lack of long-term perspective gives few opportunities to consider complementary sampling between surveys/seasons,
- ✓ poor definition and prioritization of objectives results in difficulties in effort allocation between different tasks during planning of the various surveys
- ✓ lack of coordination of winter survey activity: 4 surveys cover partly the same area
- ✓ lack of communication and coordination of survey planning results in sub-optimal survey activity.
- ✓ reduction of resources (time and money) parallel to increase demand for covering more ecosystem components, processes, and area results in mismatch between objectives and resources
- ✓ lack of an integrated data framework

Standard surveys, conducted in different seasons, are needed to be able to detect changes and monitor key processes, and the status of the ecosystem. With standard surveys we understand that surveys are conducted at a definite time, duration, location, sampling and cost to secure the deliverances. 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. This report gives 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. The monitoring program should include the following standard surveys and time frames:

- ✓ A joint ecosystem survey of at least 150 days in winter
- ✓ A joint ecosystem survey of at least 160 days in autumn
- ✓ A joint ground gear survey covering the continental slope of at least 25 days in late autumn
- ✓ Use of the part of the summer international ecosystem survey for the Nordic Seas covering the Barents Sea in early summer

Table 1 shows the existing and suggested monitoring and give a short description of standard 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 days, RU 70 days	- Demersal fishes: cod, haddock, Greenland halibut, redfishes	- Pelagic fishes: capelin, young herring, blue whiting - Interspecies interaction - Young groups of other commercial species	Oceanography
Data not used	IESNS summer	- Pelagic fishes: young herring, blue whiting	- Plankton	Oceanography
BESS-autumn (160 days)	BESS-autumn 160 days: NO-90days, RU-70 days	- 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	

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 equipments per station, processing of the samples and consequently the amount and quality of data collected will suffer. Therefore, we estimated ships time needed for different surveys with a standard sampling program, while securing some flexibility with regards to changes in distribution of target species.

The present report includes suggestions for efficiency improvement of some surveys. BESS-winter will be discussed and designed in winter 2014 by an IMR-PINRO experts group. During BESS-autumn a huge number of samples are collected and processed and therefore we recommend reduction of sample size for 0-group and non-commercially fish species from 100 to 30 (Pennington and Helle, Sochi-symposium). We recommend reducing number of stations with extended fish sampling in “Arctic area” and limit this only to ecosystem-stations. We also recommend optimalization of plankton sampling by reducing the frequency of WP-II hauls from 300 to 100 while increasing MOCNESS/Multinet, which obtain a vertical resolution of plankton data.

Organising and funding

The report summarizes how the various surveys have been planned and carried out at IMR. It was found, 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 as one project, lead by a scientific coordinator, leading a team including scientific and technical expertise. In addition, a committee should coordinate the total monitoring activity in the Barents Sea, as well as development and implementation of new methods and equipment. This committee should be lead by the program leader, leading a team including 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 surveys an ICES WG should be established. This multidisciplinary working group, in the starting phase 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 (1 - cruise planning teams, 2 – coordinating committee and 3 - multidisciplinary working group) and close communication between them, may secure optimal sampling among surveys/seasons, may increase focus on 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 diverse 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 lack 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 the most aspects of the ecosystem a range of methods and gears are applied, from water sampling using a CTD with sampling rosette, to 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 made, updated and strictly followed during 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.

Alongside this standardization, time and money should be set aside for testing out new equipment and methods for future implementation in the monitoring activity. 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 vertical distribution of the most important organisms and environmental parameters should be established.

Data products

Huge amounts of data are collected during the 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.

Estimations methods

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 and 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.

Background

The present report is the outcome of the project nr.14256 “Survey strategy in the Barents Sea”, funded by the research program “Barents Sea” and owned by Knut Sunnanå, program leader, and lead by Elena Eriksen (project coordinator).

The report is edited by Eriksen, Elena and Gjøsæter, Harald, while Johannesen, Edda; Vølstad, Jon Helge; Wienerroither, Rupert; Hallfredsson, Elvar Halldor; Thangstad, Trude Hauge; Pennington, Michael; Skjoldal, Hein Rune; Jørgensen, Lis Lindal; Ingvaldsen, Randi; Tjelmeland, Sigurd; Dalpadado, Padmini; Harbitz, Alf; Loddengaard, Turid; Wenneck, Thomas de Lange; Sunnanå Knut; Engås, Arill, Aasen, Asbjørn; Mehl, Sigbjørn; Dingsør, Gjert Endre; Korsbrekke, Knut and Skern-Mauritzen, Mette contributed to the work in various ways. The present report is based on workshops and meetings, as well as individual work carried out by the project participants. A total of 23 people at IMR took part in the project, and in addition input was received from Prozorkevich, Dmitry; Prokhorova, Tatyana; Kovalev, Jury; Smirnov, Oleg; Lubin, Pavel, and Shamray, Evgeniy at PINRO, Murmansk. After all, a survey strategy for the Barents Sea is incomplete if it only covers Norwegian surveys and monitoring; most surveys of the Barents Sea are joint Norwegian-Russian surveys. Joint work will be even more important in the future, and therefore, the suggestions for a new strategy for surveying the Barents Sea have been discussed with PINRO, e.g. at the annual science meeting in Murmansk in March 2013. A total consensus on an optimal survey strategy has not been reached; however, there is little difference in views (see discussion below).

The report is structured in the following way:
A **description of the Barents Sea ecosystem** is given, with emphasis on those features, communities, and processes that is considered most important, and consequently should be prioritized in the monitoring program.

A **description of the present system for monitoring**/surveying is given, with a short historic account on how today’s surveys developed from previous surveys/monitoring programs.

Recommendations for which species, areas, processes etc. that should be monitored during which seasons (and whether on an annual basis or more seldom) are provided, together with a description on what data products (assessments etc.) should be the outcome of those investigations.

A suggestion for a monitoring program that would fulfil these needs is given, and how this would translate into an annual survey program, including what resources (ship time, expertise) is necessary to carry out the Norwegian parts of these surveys.

General and specific recommendations, including recommendations for equipment, funding, organizing and data products

All important recommendations that need considerations when an overall monitoring strategy for IMR and a cooperative strategy for IMR and PINRO is to be decided, are listed in the executive summary.

A description of the Barents Sea ecosystem

Physical features and main processes

The Barents Sea is a large shelf area (about 1.6 million km^2) located at high latitudes between 70 and 80^{o}N to the north of Norway and Russia. The mean depth is about 230 m and the maximum depth in the western Barents Sea is about 500 m. Two archipelagos (Spitsbergen and Franz Josef Land) are located in the northern Barents Sea. The bottom topography is complex with several larger (Central bank) and smaller (North Cape Bank, Spitsbergen Bank, Thor Iversen Bank and Tidley Bank) banks and deeper trenches (Bear Island Channel, St. Anna Trough, Central Bank Basin and Murman Rise in between. In the western part the Bear Island Trough provides a deeper connection with the Norwegian Sea and in the northeast the St. Anna Trough provides a deeper connection with the Arctic Ocean via the northern Kara Sea.

The bottom topography with banks and basins steers the currents and governs the distribution of water masses (Loeng 1991). The ocean currents in the Barents Sea are dominated by flow of Atlantic Water flowing into and across the Barents Sea. The flow of Atlantic Water across the western boundary is influenced by the atmospheric pressure and winds. South-westerly winds tend to strengthen the inflow, while north-easterly winds tend to slow the inflow and may even reverse it and cause outflow events, particularly in the northern portion of the western entrance to the Barents Sea (Ingvaldsen et al. 2003). There is also inflow of Atlantic Water from the West Spitsbergen Current to the northern Barents Sea through the deeper parts of the northern shelf (Loeng et al. 1997, Matishov et al. 2009, Lind and Ingvaldsen 2012). Cold Arctic Water is found overlying the Atlantic Water in the northern Barents Sea. Some of the Arctic Water of the northern Barents Sea possibly circulates around the archipelagos, both Svalbard and Franz Josef Land. There is probably also exchange of the Arctic Water between the northern Barents Sea and the adjacent Nansen Basin of the Arctic Ocean. The ***inflowing Atlantic Water*** is relatively warm and gives boreal conditions in the western and southern part of the Barents Sea, while ***Arctic Water*** is cold and gives sub-arctic and arctic conditions in the northern part (Lind and Ingvaldsen 2012). The boreal and Arctic regimes are separated by a sharp oceanographic polar front in the western part of the Barents Sea.

Most of the sea ice in the Barents Sea is moving first-year pack ice which forms seasonally, but multi-year ice is found in the northern Barents Sea where it is partly advected in from the Arctic Ocean (Vinje 2001). The ***extent of ice cover*** is highly variable depending on the climatic conditions, and an area of about half the Barents Sea (around 0.7 million km^2) can either be ice covered in cold years or remain open in warm years. 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 blooms 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. 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 benthos (Skjoldal and Rey 1989). As the fraction of the Barents Sea covered by Atlantic water masses is higher in warm years compared to cold years, there is a higher overall production and a stronger coupling to the next level in the food web during these years.

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, while pelagic species feed predominantly on zooplankton. The ***pelagic species*** capelin, herring and polar cod are mainly plankton-feeders and constitute important links between lower and higher trophic levels in the Barents Sea ecosystem (Skjoldal and Rey 1989, Dolgov et al. 2011). Atlantic cod, Greenland halibut and long rough dab are considered to be mainly piscivorous with a variety of fish species in their diet (Dolgov et al. 2011). Capelin is a main prey species for cod in the Barents Sea and it is also important in the diet of long rough dab. However, these piscivorous species also feed on invertebrates. 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 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 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 (or avoiding cooling) for wintering and 'upstream' for ***spawning*** in spring, and east- and northward for ***feeding*** in summer. There is also large variation in diet composition over time and space, reflecting the dynamic changes in the Barents Sea ecosystem. 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 that grow and develop in the upper water layer of subarctic and low-arctic waters during the short summer season.

Box 1. Main processes:

Oceanographic processes: Inflowing of Atlantic and Arctic water. The following parameters should be observed: flux, monthly and annual temperature, water masses (type (Atlantic, Arctic, cold dense, melt) and area) and salinity, sea ice (area, concentration and southern boarder).
Biological processes**:** spring/summer phytoplankton blooms and biological production associated demographic processes (growth, reproduction, mortality) and migrations. The following parameters should be observed: onset and duration of bloom, bloom production, zooplankton (biomass, distribution, species composition and production), fish (length, weight, growth, abundance, distribution, spawning and feeding migrations, trophic level, species composition), bentos (abundance, distribution, trophic level, species composition) and sea mammals (abundance, distribution, migrations, species composition).

A description of the present system for monitoring

Aims

There are two main aims for monitoring the Barents Sea ecosystem through 'eco-cruises' and other data collections.

1. Collect updated information on the commercial fish stocks that are used in stock assessments as a basis for fisheries management advice (recommended quotas etc.).
2. Collect updated information on other parts and aspects of the ecosystem including water masses and ocean climate, plankton, benthos, fish, and marine mammals. This information allows detection and descriptions of ecosystem changes and is essential for further development of integrated assessments of ecosystem status.

These two main aims are closely linked, which reflects the trivial facts that commercial fish stocks are major components of the ecosystem, and that other parts of the ecosystem (ocean climate, prey and predators) have strong influences on the state of commercial fish stocks.

Stock assessment in a 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 1-2 years into the future from when 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 of the ecosystem which influence the stocks when projections are made and quotas are recommended. We know empirically that physical forcing (through changes in currents and water masses) has strong influence on recruitment, distribution and dynamics of fish populations. Such information can therefore in principle help us make better interpretations, assumptions and projections.

One important aspect about the ecosystem in a fishery management context is the carrying capacity for fish stocks. Carrying capacity should be regarded as a dynamic property reflecting the changing structure of the food-web part of the ecosystem (Skjoldal et al. 2004). The discussion in recent years about the situation in the Norwegian Sea illustrates the issue:

are there too much fish and too little food, and should we fish harder to ‘help’ plankton recover? For the Barents Sea we have now questions related to the record high cod stock: how will it impact its own food base, and how will food affect the development of the stock? These are issue that must be addressed as part of integrated assessments of ecosystem state.

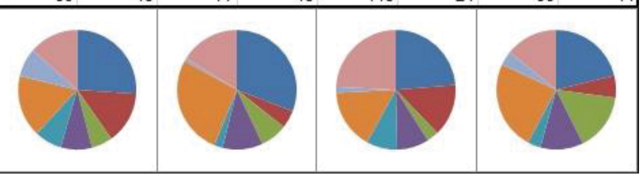
Use of ships time at IMR

The survey program covering IMR’s and other national institution’s surveys are available at imr.no, and according to this program IMR has used between 477 and 663 ships days in the Barents Sea during the period 2010-2013 (Table 1). The days at sea have been reduced since 2010. Surveys which collect and process data for stock advice of commercially important Barents Sea species are the Norwegian-Russian winter survey (NRWS) and Ecosystem survey (BESS-autumn). These are often called standard or traditional surveys. Time at sea for these surveys were reduced from 173 (2010) to 131 (2013) days. Surveys which covered area along the Norwegian coast were separated from the Barents Sea surveys, these coastal surveys collect and process data for stock advice of coastal fish species and NEA cod.

IMR has mostly used own vessels for surveys which deliver data for stock assessment and advices for commercially important species (capelin, cod, haddock, redfishes, Greenland halibut and wolffishes, saithe and coastal cod). NRWS and BESS-autumn are the largest surveys at IMR and PINRO, and therefore planning and carrying out are time consuming and needs good cooperation. In some years these surveys were partly conducted by hired vessels that complicated the planning and carrying out and decreased data quality. Other surveys which deliver data for stock advice for king crab and whales and seals have usually used hired vessels due to needs of small vessels.

Table 1. Use of ships time (in days and percentage) in the Barents Sea for different purposes.

Use of ships time	2010		2011		2012		2013	
	days	%	days	%	days	%	days	%
The surveys in the Barents Sea	**663**	100	**506**	100	**600**	100	**643**	100
use of own vessels	439	66	140	28	304	51	374	58
Stocks advice								
FISH: pelagic and demersal species	**173**	**26**	**147**	**29**	**142**	**24**	**131**	**20**
use of own vessels	120	69	76	52	71	50	117	89
King crab	**38**	6	**35**	7	**19**	3	**96**	15
use of own vessels	0	0	0	0	0	0	0	0
FISH: Coastal species and NEA cod	**94**	14	**52**	10	**85**	14	**61**	9
use of own vessels	94	100	23	44	85	100	61	100
Whales and seals	**56**	8	**52**	10	**52**	9	**72**	11
use of own vessels	0	0	0	0	0	0	21	29
Other purposes:	**302**	**46**	**220**	**43**	**302**	**50**	**283**	**44**
use of own vessels	**225**	51	**80**	57	**148**	49	**175**	47
Mareano	49	7	11	2	50	8	22	3
Equipment and observation technology	112	17	128	25	97	16	149	23
Oceanography and marine enviroment	52	8	4	1	10	2	24	4
Other	89	13	77	15	145	24	88	14



Survey activity in the Barents Sea

The monitoring of the BS ecosystem is a joint effort between Norway and Russia, and collaboration between the two countries has been developed since 1954. Survey activities aimed to monitor the commercially important species and gather information about environmental features, important for ecosystem processes and biodiversity.

In this report we give information on some of the surveys aimed for stock advice of commercially important Barents Sea species and their environment, but several stocks are found both in the Norwegian Sea and the Barents Sea during their life-cycle. In order to account for that, 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 at the continental slope (Greenland halibut) along the slope 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.

Table 2. General information and abbreviation for various surveys.

Survey	**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

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

Background

A combined acoustic and bottom trawl survey to obtain indices of abundance and estimates of length and weight at age of 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. The trawl gear was changed at the same time, as an inner net was added. This increased the catchability of small fish. The methodology (including changes over time) is described in Jakobsen et al. (1997) and Mehl et al. (in press). Since 2000 Russian vessels participated, but not every year (not 2006-2007). In the years with Russian participation the coverage was more complete, especially in 2008 and 2011. In 2009, 2010 and 2012 the coverage in the east was more limited due to strict rules regarding handling of the catch, bad weather and logistic problems.

Table 3. Time series of investigations and their start (stop) date included in NRWS. To be included in the table, the investigation has to been carried out annually with consistent area coverage and survey methods.

Investigation	Methods	Start/ stop
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

Timing

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

However, in recent years immature cod have been distributed outside (north and east of) the survey area (Johansen et al 2013). This influenced the validity of the abundance indices. Also, a large proportion of the mature haddock (age 6 and older) and some of the mature cod are on its spawning migration south-westwards and therefore out of the investigated area, and some of them recorded by Lofoten survey (see below). Also some cod may be recorded both by this survey and the Lofoten survey. Finally, no coverage of arctic species is possible due to ice coverage. During winter, ice coverage is largest and difficult weather conditions can hamper the survey.

Objectives

The target species are cod and haddock, but abundance indices have also been worked out for the redfish species since 1986, Greenland halibut since 1990, and blue whiting since 2001. The main aims are to

- Obtain acoustic abundance indices by length and age for cod and haddock
- Obtain swept area abundance indices by length (and age) for cod haddock, redfish and Greenland halibut.
- Map the geographical distribution of those fish stocks
- Estimate length, weight and maturity at age for those stocks
- Collect and analyse stomach samples from cod, for estimating predation by cod
- Collect occasional oceanographic data from winter

Survey design

The winter survey is a stratified combined acoustic and bottom trawl survey. Stations for bottom trawling within strata were allocated randomly from 1981–1990 in the standard survey, and then systematically from 1992 and onwards (see Jakobsen et al. 1997 for more details on trawl gear, protocol, and design.) The positions of the trawl stations used for swept area stock index estimation are pre-defined in the standard survey protocol, while additional trawls hauls may be made for the purpose of interpretation of echograms. The winter survey covered an area of 88 835 km^2 in the Norwegian Economic Zone (NEZ) from 1981-1992 and was expanded in 1993 to include the Russian Economic Zone (REZ) and the Grey zone. The area covered and the number of trawl stations in the expanded winter survey have varied from 260 000 km^2 and 176 trawl stations to more than 690 000 km^2 and 394 trawl stations (Pennington et al. 2011).When the swept area investigations started in 1981 the survey area was divided into four main areas (A, B, C and D) and 35 strata. Since 1996 a revised strata system with 23 strata has been used. The main reason for reducing the number of strata was the need for a sufficient number of trawl stations in each stratum to get reliable estimates of density and variance. In later years a few pre-defined trawl stations have been performed north of the strata system due to increased abundance of cod in these areas. However, the data are so far not included in the estimation of abundance indices.

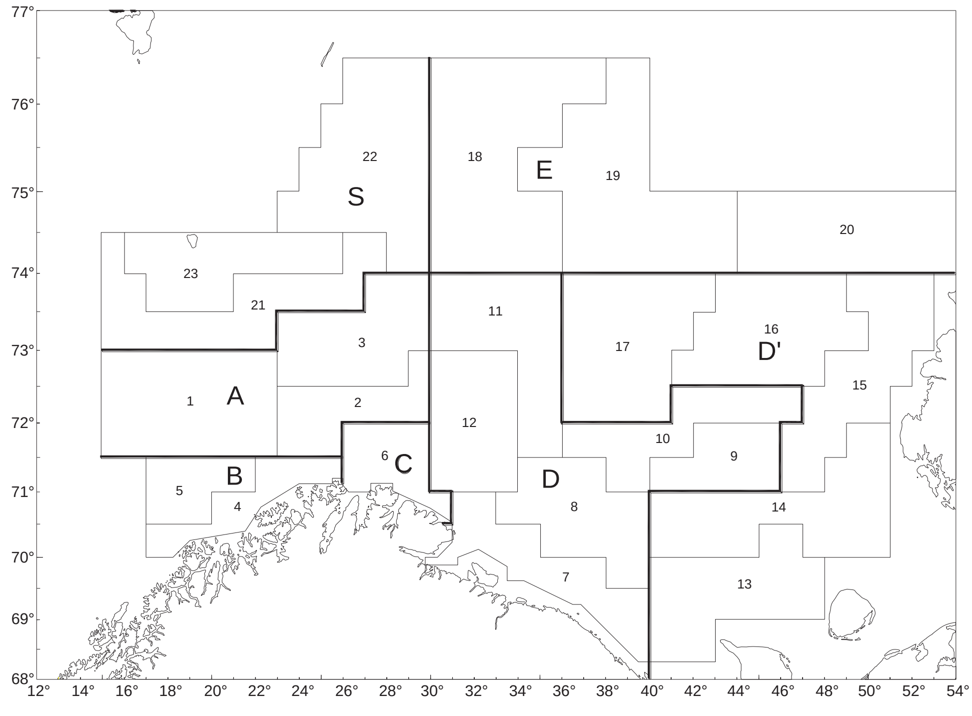


Figure 1. Strata (1-23) and main areas (A, B, C, D, D’, E and S) used for swept area estimations. The Main Areas are also used for acoustic estimation**.**

The detailed information about acoustic measurements, trawling procedure, calculation methods and historic overview is available in “Survey manual”.

The main results 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. Results are also widely used in internal and external projects.

Norwegian spawning cod survey (NSCS)

The ”skrei” survey is an acoustic survey carried out with one research vessel in the area Lofoten and Vesterålen during the last half of March, and the aim of the survey is to map the abundance and distribution of the spawning stock.

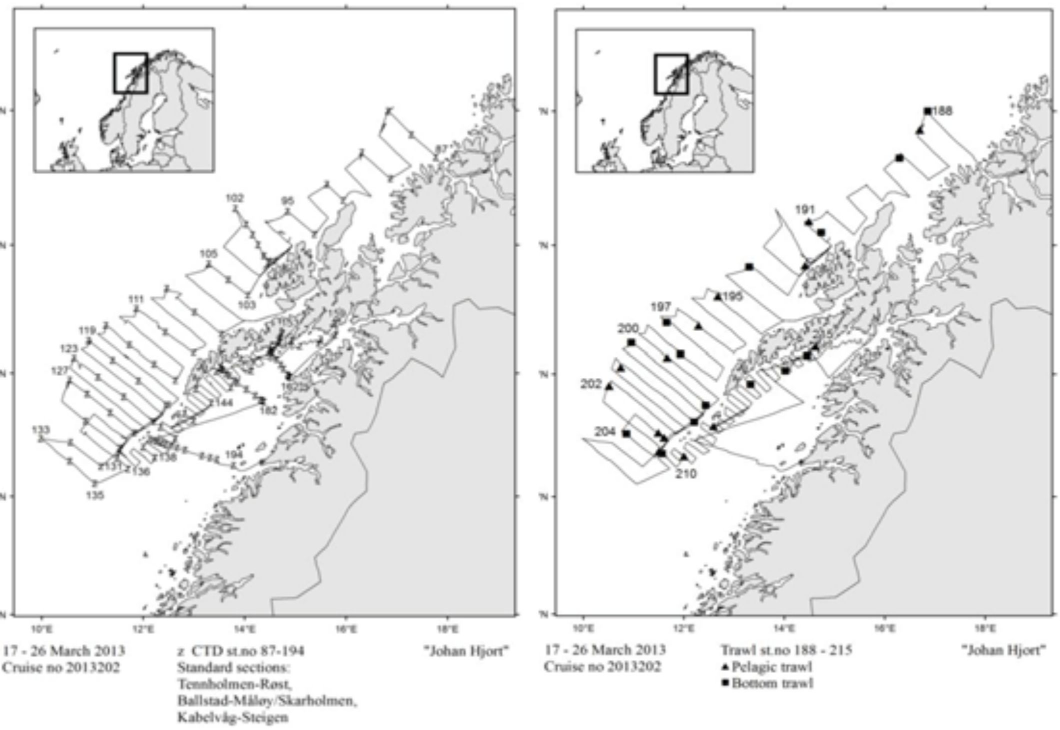


Figure 2. Survey map for NSCS survey 2013. CTD stations are shown at left, while trawl (pelagic and bottom) station are shown at right.

The cod has migrated to Lofoten to spawn for centuries, and an important fishery has been carried out during this period since people settled at the coast in this area. As early as 1860 the well-known researcher G.O. Sars visited Lofoten to study cod eggs and larvae. The Institute of Marine Research has for a long period mapped the spawning migration of cod, and since 1985 acoustic surveys have been carried out annually.

The aim of these surveys is to map the geographic distribution of mature cod and to estimate the number of fish, and the mean length, weight, and maturity in each age group. Abundance indices are given based on acoustic measurements and composition of trawl catches. These surveys are very informative in the stock assessments done by the ICES expert group AFWG, and we still miss some knowledge about the basic processes connected to the cod spawning in Lofoten. For that reason, temperature and salinity are measured, egg samples are taken from net tows, and genetic analyses are carried out.

Cod are also marked, to study spawning behaviour and migration patterns.

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

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

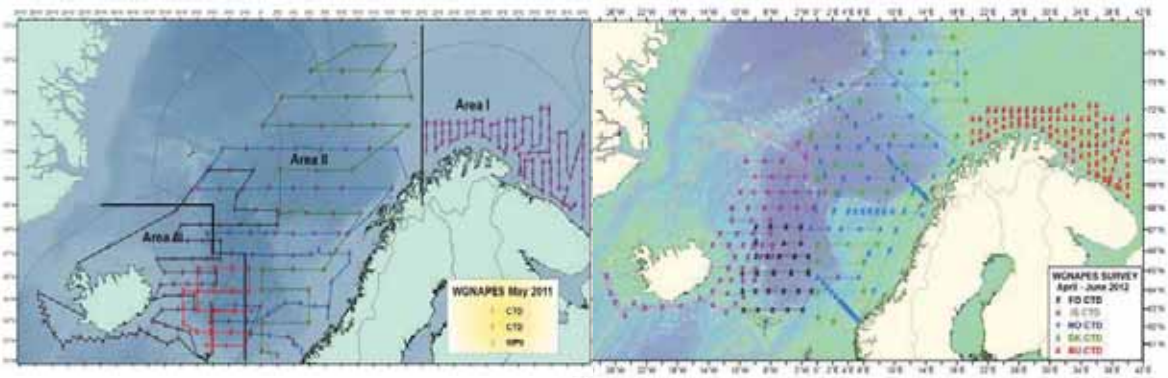


Figure 3. Cruise track, CTD (left) and trawl (right) stations by country for the International ecosystem survey in the Nordic Seas in April-June 2012.

All vessels use a large or medium-sized pelagic trawl as the main tool for biological sampling. Catches from trawl hauls are sorted and weighed; fish are identified to species level, when possible, and other taxa to higher taxonomic levels. Normally a subsample of 30–100 herring and blue whiting are sexed, aged, and measured for length and weight, and their maturity status estimated using established methods. The hydrographical and plankton stations are shown in Figure 3. All vessels collect hydrographical data using a SBE 911 CTD. Maximum sampling depth is 1000 m. Zooplankton is sampled by a WPII on all vessels except the Russian vessel which use a Juday net, according to the standard procedure for the surveys. Mesh sizes are 180 or 200 μm. The net is hauled vertically from 200 m or the bottom to the surface.

This survey is a joint survey and, therefore, all data are available to all participants.

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

Background

The autumn ecosystem survey of the Barents Sea (BESS) emerged from a conglomerate of surveys previously carried out to study various aspects of the ecosystem. Among these were the 0-group survey, the acoustic survey for pelagic fish (both of which included hydrography and plankton investigations), juvenile Greenland halibut and redfish survey, a shrimp survey, and the summer surveys for ground fish. Some of these surveys were conducted jointly with PINRO, Russia.

These surveys did to various degrees support single stock fisheries assessments (capelin, shrimp, juvenile Greenland halibut and redfish) and provided time series of specific ecosystem components (e.g. 0-group survey, standardized since 1980, young herring since 1985, polar cod since 1986, plankton since 1989 and hydrographic conditions since 1970) and providing data for estimation of cod consumption.

When the ecosystem survey was developed around 2003-04, some additional investigations were added: benthos by-catch, sea mammals, sea birds, garbage and pollution, and the plankton investigations were intensified compared to previous surveys. Since 2005 also the Norwegian shrimp survey (demersal trawl survey) was included into the multipurpose survey that we refer to as the BESS. Since 2010 the areas around Svalbard (west, north and north-east) were more densely covered with regards to depth, and this part of the coverage is termed the Arctic Ecosystem survey and is funded separately by the Barents Sea program (IMR).

Table 4. Time series of investigations presently included in BESS and their start date. To be included in the table the investigation has to been carried out annually with consistent area coverage and survey methods.

Investigation	**Methods**	**Start**
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
Benthos by-catch	Demersal trawl	2005
Marine mammals and birds	Observations	2003 (Norwegian boats)
Garbage	Surface observations Pelagic trawl Demersal trawl	2010
Pollution	CTD, grabs	2003

Timing and area coverage

The most of, or the whole Barents Sea is 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 season. 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 of the various stocks in the current year. This is a period when the 0-group of commercially and ecologically important fish is large, and therefore effectively caught by trawls, at the same time settlement processes of 0-group of demersal species has not begun.

For adult ground fish (cod, haddock, redfish, and Greenland halibut), shrimp and others, this period is not necessarily the most ideal, taking fish behaviour into consideration. Acoustic indices of cod and haddock have not been calculated from this survey, although the data for making such indices are available.

The autumn period is ideal for assessing the capelin stock with the purpose of giving quota advice for the winter fishery. This is due to the additional mortality and growth up to the start of the fishing season is limited, and the maturing part of the stock, which forms the basis for the quota advice, can be assessed.

Objectives

The objectives were largely adopted from earlier surveys, however additional objectives were also integrated to monitor and assess the whole ecosystem.

Objectives were to monitor:

- Marine environment
- Plankton community
- Pelagic community
- Demersal community
- Trophic interactions
- Biodiversity
- Marine mammals and seabirds

Survey design

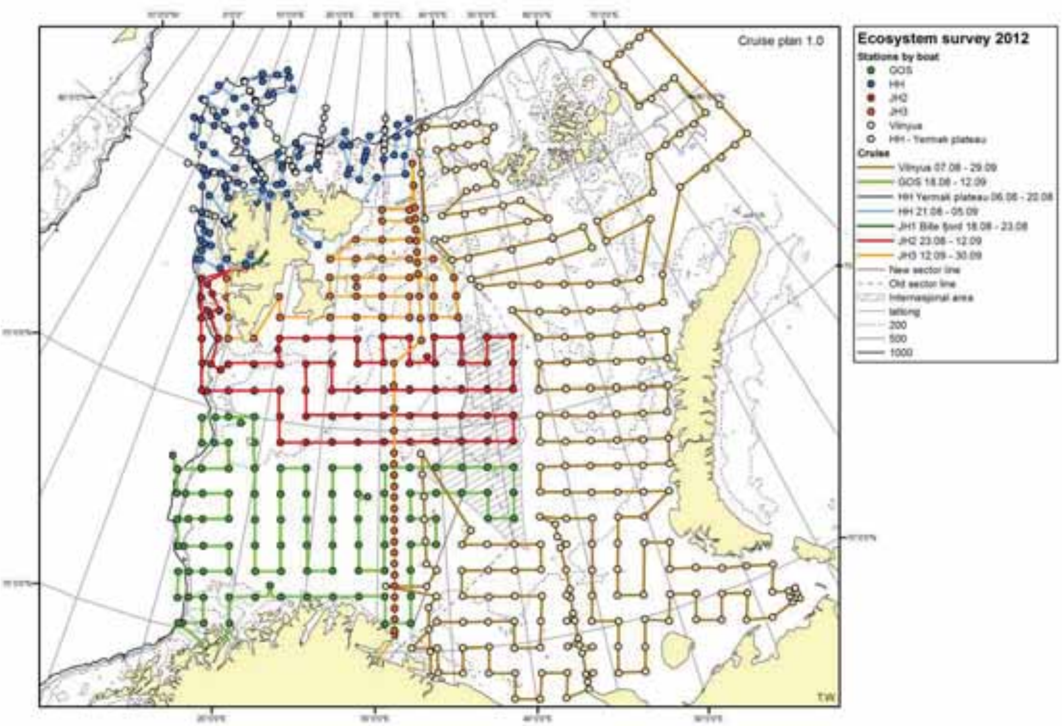


Figure 4. Map of the survey area BESS-autumn survey in 2012.

The survey design of BESS-autumn 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 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 hauls.

Additional to the regular grid, the "capelin area" south-east and east of the Spitsbergen archipelago is more densely covered. This is due to its importance for the mature capelin, which stays in dense schools, and therefore this area gives an appreciable contribution to the capelin assessment.

The two most important areas for shrimp is the continental slope on the west and north of Spitsbergen and the bank areas in central Barents Sea, in particular the Hopen Deep. A depth and area stratified sampling system is used west and north of Spitsbergen, and an area stratified system that is now integrated in the ordinary grid and strata system is used in the Barents sea including the Hopen Deep. The combination of these two systems is needed to get sufficient sampling and determination of the length-, sex-, stage- shrimp composition. A depth stratified and random bottom sampling is needed to get sufficient sampling determination of the length-, sex-, stage- shrimp composition.

During the nine years of BESS better understanding of the ecosystem components and processes based on output of the survey has been obtained. In later years this knowledge has been documented in more than 70 scientific papers and 14 survey reports. This knowledge together with other sources of information has been assembled in the books: "Ecosystem Barents Sea" (2009, ISBN 978-8251924610) and "The Barents Sea ecosystem, resources, management. Half a century of Russian-Norwegian cooperation" (2011, ISBN 978-8251925457). Therefore, BESS have a high level of dissemination of results in the form of reports, stock assessments, management plan, 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 the survey has been to describe the adult part of the Greenland halibut (*Reinhardtius hippoglossoides*) stock in this area (Figure 5). As in 2009 an improved sampling regime concerning the by-catch species, resulting in a more appropriate description of these species with regard to species distribution and species number. Recently the survey also has focused on the by-catch species, and the survey strategy has to a certain extent been adapted to this task.

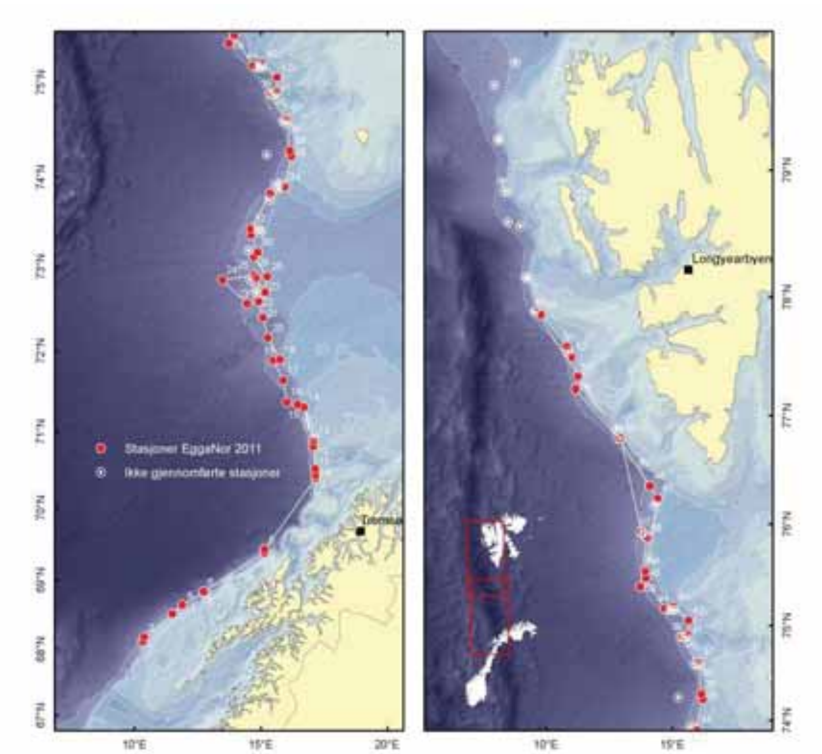


Figure 5. Map of the survey area, showing realized (red dots) and planned (white dots) trawl stations.

In 2011 a long-term survey strategy for Norwegian deep-sea fish surveys was developed at IMR (Harbitz 2011). In the plan the current survey is intended to maintain the time series, but biennially from now on. The strategy recommended a substantial reduction in effort (ca. 50% reduction in number of stations), because the precision of the abundance biomass estimate was expected to be low even after such a reduction (*CV* expected to be c. 15%). This year the weather condition demanded further reduction in number of stations, and this is reflected in increased uncertainty in abundance estimates.

The 2011 survey lasted from 20 November to 6 December. This is a bit later in the year compared to previous years when surveys have been in August-October. This change moves the survey closer to time of peak spawning for Greenland halibut in December/January. Thus the expectation would be that the shift in time is towards higher densities at the spawning grounds compared to earlier in the year.

Russian late autumn-winter survey (RAWS)

Background

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 October-December period. The survey was conducted by two-three vessels, and it was used approximately 150 days at sea between the end of 1980th and mid of 19990th , while both vessels participations was reduced to two vessels and duration was reduced to 90-100 days at sea due to decreased funding.

Table 5. Russian late autumn-winter survey. Time series of investigations and their start (stop) date included in RAWS. To be included in the table the investigation has to been carried out annually with consistent area coverage and survey methods.

Investigation	**Methods**	**Start/ stop**
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/

Timing

During late autumn-winter cod is 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 entire stock in late autumn, since cod has not yet started spawning migration. There may be some ice problems, but less than during Norwegian winter survey.

Objectives

The target species are cod and haddock, but abundance indices have also been calculated for other demersal fishes. The main aims are to:

- Obtain acoustic abundance indices by length and age for cod, haddock, redfish and Greenland halibut
- Obtain swept area abundance indices by length (and age) for cod haddock, redfish and Greenland halibut.
- Map the geographical distribution of those fish stocks
- Estimate length, weight and maturity at age for those stocks
- Collect and analyse stomach samples from cod, for estimating predation by cod provide a long time series of the overwintering stock of krill, using a bag attached to the trawl

Survey design

Survey design is based on variable station grid. The route of each survey, periods and a number of stations are assigned depending on target commercial species distribution. The design of the survey is trying to cover the stock to the zero distribution line in shortest possible time, to avoid problems with migration.

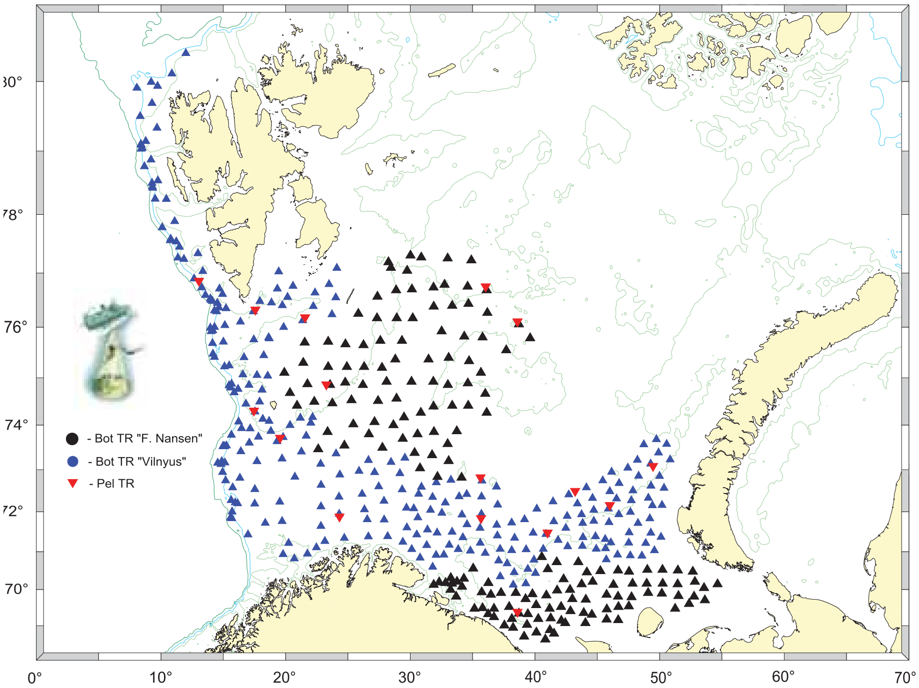


Figure 6. Survey map in 2001.

Trawling on echo registrations are carried out when necessary using the Russian bottom trawl (number 2283-02 and with mesh size of 16 mm in the cod end, attached net for sampling of krill) which can be operated down to 1200 m.
The bottom trawl used during the RAWS is less appropriate for 0-2 years cod and haddock compared with the Campelen trawl, used during the NRWS.
The results concerning cod, haddock and Greenland halibut from the survey are input data to analytical assessment models (VPA) in Arctic fisheries working group in ICES. The surveys are also reported in various internal and external reports and scientific publications.

Overview for funding and organising the present monitoring at IMR

Organising and conducting ecosystem surveys demands a tremendous effort: planning, carrying out, data processing and reporting.
BESS-autumn have been organized and financed by different ways at IMR: as

- one project lead by one person (coordinator)
- several projects, where each project was responsible for financing own investigations (fish, plankton etc). A coordinator combined the suggestions from each project and designed the survey

one project lead by a team, and team-members were responsible for different investigations

- one project lead by a team, and team-members were responsible for different tasks: planning, caring out, reporting and budgeting
- one project including several surveys (BESS-autumn and NRWS), where several coordinators lead their own surveys

In the recent years BESS-autumn was funded mostly by project “Ecosystem survey”, owned by “Barents Sea research program”. However, plankton investigations (cost at sea and processing of samples in lab) were funded by the plankton project, which was also owned by "Barents Sea research program". Participation of different experts is funded by other Research programs (oceanographers and chemists) and also by "Barents Sea research program" (geneticist and benthos experts). Consequently, this makes it difficult to reconstruct the total cost the "BESS-autumn", and real effort for planning, conducting and reporting of the BESS-autumn. The present way of funding standard investigations make implementation of the surveys even more difficult and may negatively influence planning, carrying out, data and samples processing, and reporting.

We tried to reconstruct the cost for BESS-autumn for the period 2010-2013 based on "Maconomy" and summarised all available information in the tables 3 and 4, although the real cost, as mentioned above, is larger.

Table 6. The calculated costs for carrying out BESS-autumn during 2010-2013, and costs for different investigations are given separately.

	2010	2011	2012	2013	2014
Cruise leader	787 656	727 216	839 800	1 009 620	855 000
Oseanography	202 236	201 264			
Plankton	1 309 212	1 274 672	1 422 720	1 955 340	3 135 000
Pelagic fish	2 022 360	1 667 616	1 719 120	1 827 540	
Bottom fish/shrimp	1 852 056	3 028 544	3 082 560	3 987 360	5 343 750
Sea mammals	325 600	320 000	619 680	1 784 490	450 000
Pollution	63 864		622 440		
Genetics		143 760			
Benthos		448 800	532 600	1 060 740	
Survey equipment			138 320		
Other			395 200	575 100	1 000 000
Experts			158 080	166 140	
Total days at sea	734	905	1 089	981	1 433
Total cost	**6 562 984**	**7 811 872**	**9 530 520**	**12 366 330**	**13 984 750**

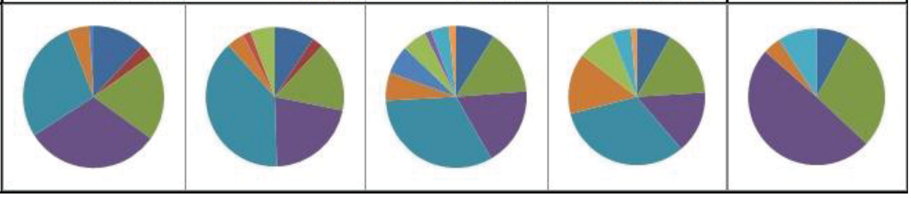


Table 6 represents detailed information of cost for different surveys and total estimated cost for the Research program "The Barents Sea" and the total estimated cost for the IMR. All expenses, which are related to planning, data processing and reporting is presented in "Cost at land", while all expenses, which are related to salary, goods and services is presented in "Other costs". Stomach samples and plankton samples are processed in the lab at IMR, and therefore we include cost for this in "Cost for sample processing". Costs for own and hired vessels are presented separately. All expenses, which are related to vessel's cost and some expenses for conducting additional investigations during surveys are included in the "Total costs for IMR", and BESS-autumn in this post includes expenses for persons which are responsible for equipment on board. Data for table 6 were extracted from "Maconomy" at IMR.

In contrast to BESS-autumn, the NRWS is owned by “Barents Sea research program”. However, NRWS and Lofoten surveys have also been organized and financed by different ways: as

– one project which was lead by one person (coordinator) at IMR .
– two separate projects
– one project which was lead by one person and three coordinators.

Our experience is that team organisation of survey coordination is preferred, since planning is time consuming, and interactions with several scientific disciplines is challenging, Underestimation of this work may negatively influence planning and conducting of the survey (WKECES, 2012).

Our experience is also that one project is a better way of funding the survey’s planning, coordinating and carrying out, and separate budgets for each survey may give better overview over used resources and costs. Cost of some surveys shows only the finale cost after the surveys were decreased for different reasons (financial or technical problems with vessels etc).

Table 7. Detailed information about the cost for different surveys and total cost for the Research program “The Barents Sea” and for IMR

BESS-Autumn	2010	2011	2012
cost at land	527 662	3 680 025	4 640 898
cost at sea	6 237 384	5 782 472	7 134 720
cost for own vessels	9 139 174	11 179 421	12 572 695
cost for hired vessel(s)	3 309 591	2 717 340	2 826 030
Cost for sample processing	1 352 000	1 216 000	1 043 000
Other cost	325 600	2 029 400	2 395 800
TOTAL COST FOR RESEARCH PROGRAM	8 442 646	12 707 897	15 214 418
TOTAL COST FOR IMR	34 387 676	39 411 441	45 160 943
NRWS			
cost at land	6 688 891	0	1 089 503
cost at sea	4 399 464	2 996 975	2 327 214
cost for own vessels	5 797 818	5 497 184	0
cost for hired vessel(s)	5 574 048	5 253 524	6 186 471
Cost for sample processing	794000	614000	509 000
Other cost	31 434	0	91 741
TOTAL COST FOR RESEARCH PROGRAM	11 913 789	3 610 975	4 017 458
TOTAL COST FOR IMR	23 285 655	14 361 683	10 203 929
Lofoten survey			
cost at land	0	0	423 622
cost at sea	1 292 481	913 954	685 688
cost for own vessels	3 138 420	3 212 416	3 246 234
cost for hired vessel(s)	0	0	0
Other cost	0	250 800	326 196
TOTAL COST FOR RESEARCH PROGRAM	1 292 481	1 164 754	1 435 506
TOTAL COST FOR IMR	4 430 901	4 377 170	4 681 740
EGGA-NOR			
cost at land		814 439	
cost at sea		304 935	
cost for own vessels		2 858 544	
cost for hired vessel(s)		0	
Other cost		375 404	
TOTAL COST FOR RESEARCH PROGRAM		1 494 778	
TOTAL COST FOR IMR		5 848 100	
TOTAL COST FOR RESEARCH PROGRAM	21 648 916	18 978 404	20 667 382
TOTAL COST FOR IMR	62 104 232	63 998 394	60 046 612

Recommendations for which species, areas, processes etc. that should be monitored during which seasons

The monitoring of oceanographic processes

The aim of the oceanographic investigations is to obtain the horizontal and vertical distribution of water temperature, salinity and nutrients in the Barents Sea. Special attention is taken on the Atlantic inflow in the southwest as this inflow has profound impact on the Barents Sea temperatures. The investigation involves taking in-depth profiles over the total investigated area and along the standard oceanographic sections (Figure 7).

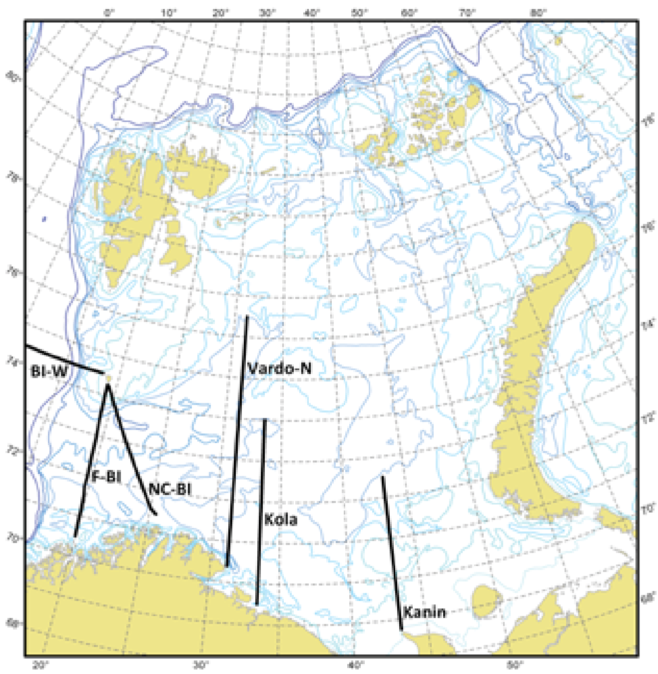


Figure 7. The sections Fugløya–Bear Island (F-BI), Vardø–North (Vardø-N), Bear Island–West (BI-W), North Cape–Bear Island (NC-BI), Kola, and Kanin in the Barents Sea.

Box 2. Monitoring the oceanographic conditions:
Oceanographic sections: Norwegian: Fugløya-Bear Island, Vardø-North, Bear Island-West (overlaps with Russian section). Russian: North Cape–Bear Island, Kola and Kanin
Area surveys: temperature and salinity

Spatial data (temperature and salinity) have been collected by CTD and water samples (for nutrients) taken at each trawl station. The sampling was conducted either before or after trawling.

Ecologically important species and groups

More than 200 species of fish have been recorded in the Barents Sea. There are 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).

The plankton community

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 planktivorous fish. The larger zooplankton is also important for top predators such as birds, sea mammals and cod.

Copepods fall within the meso-zooplankton (0.2-20 mm) category. The most common copepods in the Barents Sea belong to the genera *Calanus*, *Metridia*, *Pseudocalanus*, *Oithona* and *Oncaea*. The most dominant copepod species in the Atlantic boreal waters is *Calanus finmarchicus*. The inflowing Atlantic water brings with it *Calanus finmarchicus* and re-supplies the stock in the southern Barents Sea that otherwise would have been depleted by predation and expatriated as the water is cooled and transformed into Arctic water. The larval forms of *C. finmarchicus* are the principal food of most fish larvae, while the adults are food for pelagic fish species. The large lipid rich *C. glacialis* form an important part of the Arctic zooplankton community in the Barents Sea.

Euphausiids and amphipods belong to macro zooplankton (2-20 cm). In the Barents Sea ecosystem, *Thysanoessa inermis* (south-western and central parts) is an important species in the food web (Dalpadado and Skjoldal 1991, 1996), *Thysanoessa raschii* (south-eastern part, Drobysheva 1994) and *Meganyctiphanes norvegica*, are advected into the western Barents Sea and is a common euphausiids species. Euphausiids are an important part of the diets of sea mammals, seabirds and fishes. In addition, in the recent years the warm water species, *Nematoscelis megalops* is regularly observed, most likely introduced by influx of the Atlantic current. The mean annual euphausiids biomass was estimated to be 19 million tonnes in wet weight (maximum 40 million tonnes 1980-2009, Eriksen and Dalpadado, 2011). The main copepod and euphausiids species are predominantly herbivorous, constituting a key link to the higher trophic levels (Falk-Petersen et al. 2000; Pasternak et al. 2001; Dalpadado et al. 2008).
The pelagic amphipods are dominated by hyperiids; *Themisto abyssorum* in Atlantic boreal waters and *T. libellula* in the Arctic waters. Amphipods are primarily carnivorous, feeding mainly on *Calanus* (Dalpadado et al. 2008). In the Arctic food web, *T. libellula* is the main prey of polar cod, seabirds and whales (Kovacs and Lydersen, 2006). The ice associated (sympagic) amphipods such as *Gammarus wilkitzkii*, *Apherusa glacialis* and *Onismus* spp. are also important components of the Arctic food web.

Cyanea capillata is a northern boreal species and it is the most common and wide spread scyphozoan jellyfish in the Barents Sea (Zelickman, 1972). The long term average (1980-2009) of jellyfish was ca. 1 million tonne (max 5 million tonnes, Eriksen et al. 2012). The bulk of the jellyfish were observed in the central parts of the Barents Sea, which is a core area for most 0-group fishes (cod, haddock, herring and capelin).

> **Box 3. Monitoring the most ecologically important plankton species:**
> **Copepods**: *Metridia lucens, Metridia longa, Calanus glacialis, Calanus hyperboreus, Calanus finmarchicus, Pareuchaeta norvegica, Pareuchaeta glacialis, Pareuchaeta* spp.
> **Amphipods:** *Onisimus nanseni, Onisimus glacialis, Gammarus wilkitzkii, Themisto abyssorum, Themisto libellula, Themisto compressa*
> **Euphausiids:** *Meganyctiphanes norvegica, Thysanoessa inermis, Thysanoessa longicaudata, Thysanoessa raschii*
> **Pteropods:** *Limacina helicina, Limacina retroversa*
> **Cnidaria**: *Cyanea capillata*
> Chaetognatha

Appendix 1 presents the most ecologically important plankton and the optimal time for the monitoring.

The fish community

The Barents Sea contains several large stocks of fish that are key species in the Barents Sea food web. These include the Barents Sea ***capelin*** (*Mallotus villosus*) stock mentioned, and also large (and commercially important) stocks of ***cod*** (*Gadus morhua*), ***haddock*** (*Melanogrammus aeglefinus*), **Greenland halibut** (*Reinhardtius hippoglossoides*)). There are two stocks of ***polar cod*** (*Boreogadus saida*) and a stock of ***long-rough dab*** (*Hippoglossoides platessoides*) are large and therefor important ecologically, but exploited only to a limited extent. In total more than 200 fish species from 66 families have been recorded in the Barents Sea (Dolgov et al. 2011). Around 100 fish species are caught regularly in scientific trawl surveys and were included in a recently published atlas of the Barents Sea fishes (Wienerroither et al. 2011). Some species have their main feeding (e.g. cod) or nursery (e.g. herring) area in the Barents Sea, but spawn in the Norwegian Sea along the coast of Norway. Other species, whose main feeding areas are in the Norwegian Sea, regularly visit the Barents Sea during their feeding migrations in summer and throughout the year when the stock is large (e.g. blue whiting), and some species have occasionally appeared in the Barents Sea due to high population levels and inflow of Atlantic water (e.g. snake pipefish). For many of the non-commercial species, their life cycle, migration pattern and spawning areas are poorly known. Barents Sea fish species can be classified into three main ***bio-geographical groups***: Arctic, Boreal and Widely distributed and climate change will influence them different.

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.

Box 4. Monitoring the most important fish species:
Ecological dominance:
Dominant pelagic: capelin, polar cod, young herring, blue whiting,
Dominant demersal: cod, haddock, long rough dab, Greenland halibut, golden redfish, and beaked redfish
Commercial importance:
Pelagic: capelin, polar cod, herring, blue whiting
Demersal: cod, haddock, Greenland halibut, redfishes, wolffishes (to a limited extent)
Sensitivity species: most arctic species due to slow growth and low fecundity, redlist: golden redfish
Important representatives for bio-geographic groups:
Boreal: Lesser sandeel, lumpsucker, thorny skate, *Lycodes gracilis*, Norway pout
Arctic: Polar cod, Arctic flounder, Bigeye sculpin, Arctic skate, *Lycodes pallidus*
Widely: Greenland shark, Atlantic poacher, Ribbed sculpin

Appendix 2 presents the most important fish species according to these criteria and optimal coverage periods for each of them.

The benthos community

More than 300 invertebrate taxa have been recorded during the ecosystem surveys from year 2006 to 2012. Since the research trawl used is a modified shrimp (Campelen) trawl the commercially important northern shrimp (*Pandalus borealis*) is overall one of the most dominating species in the invertebrate catch component. Shrimps are found all over the Barents Sea, but occur most densely in the central and northern parts. The most dominating megafaunal groups across all stations sampled are Echinodermata and Crustacea in abundance and Porifera, Echinodermata and Crustacea in biomass. The echinoderms are widely distributed in the central parts of the Barents Sea, while crustaceans such as the red king crab (*Paralithodes camschaticus*) have a biomass hotspot in the south eastern Barents Sea and porifera (sponges) one in the Atlantic current in the western Barents Sea.

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. Arctic taxa are found in the northern parts and boreal subarctic taxa mostly on the shallow waters on the Spitsbergen Bank, but also in the south-eastern part of the Barents Sea. Boreal fauna largely occur in areas influenced by the Norwegian Coastal Current along the coast of Norway and Russia. A transitional zone, including both boreal and arctic taxa, is identified in deeper waters in central and in northern Barents Sea. Boreal-arctic species dominate the biomass of benthos in the Barents Sea (as well as throughout the Arctic shelf). According to Galkin (1987), Kiyko and Pogrebov (1997), any deviations from the long-term mean have a negative impact on boreal-arctic species by decreasing their abundance and area of distribution. Widely distributed and dominant species in the Barents Sea such as the boreal-arctic *Ctenodiscus crispatus* and *Ophiura sarsi* shows increasing biomasses with increasing temperatures, while arctic species such as the bivalve *Bathyarca glacialis* are decreasing. The opposite is the case with decreasing temperatures (Frolova et al 2007). Investigations of the distribution of vulnerable species toward bottom trawling are currently undertaken.

Box 5. Monitoring the 10 most ecologically important bentos species communities:
COM *Gorgonacephalus* spp/Ophiuroidea
COM *Gorgonacephalus arcticus*/*Ctenodiscus crispatus*
COM *Geodia* sp/ *Pontaster tenuispinus*
COM *Paralithodes camtschaticus*/ Actiniaria
COM *Hormathia sp/* Porifera
COM *Sclerocrangon boreas*/ *Hyas* sp/ *Sabinea septemcarinata*
COM *Strongylocentrotus* sp/ *S. septemcarinata*
COM *Ophiopleura borealis*/ *Ophiacantha bidentata*/ *S. septemcarinata*
COM *Metridium senile*/ *Brisaster fragiles*/*Ophiacantha bidentata*
COM Actiniaria/ *Hiatella arctica*

Marine mammals

About 25 species of marine mammals regularly occur in the Barents Sea, comprising 7 pinnipeds (seals and walruses), 12 large cetaceans (large whales), 5 small cetaceans (porpoises and dolphins) and the polar bear (*Ursus maritimus*) (Michalsen et al. 2011). Some of these species have temperate mating and calving areas, while summer feeding areas are located in the Barents Sea (e.g. minke whale *Balaenoptera acutorostrata*), others reside in the Barents Sea all year round (e.g. white-beaked dolphin *Lagenorhynchus albirostris* and harbour porpoise *Phocoena phocoena*). Some marine mammals are rare because of historic exploitation, such as the bowhead whale (*Balaena mysticetus)* which is still on the verge of extinction).

Box 6. Monitoring the sea mammals:
Phocidae: harp seals
Delphinidae: white - beaked dolphins, killer whales other toothed whales
Physeteridae: sperm whales
Balaenopteridae: humpback whales, minke whales, fin whales

Monitoring the trophic interaction

A coordinated study between PINRO and IMR on the diet of capelin and polar cod in the Barents Sea was initiated in 2005 and 2007 respectively, and main aims with these investigations are identifying of key feeding areas of capelin and polar cod, their main prey, climate impact on food and feeding conditions, and interactions with zooplankton. Stomach content data of cod have been sampled since 1984, and this is thus a long and very valuable time series giving a lot of management-relevant and ecological information about the Barents Sea ecosystem. The goal of the investigations is to monitor the diet of cod, which is the main predator in the ecosystem.

Box 7. Monitoring the trophic interactions:
Cod: 1 stomach pr 5 cm length group at all stations where biological samples of cod are taken
Polar cod: the stomachs of the first 10 are frozen at some stations
Capelin: the stomachs of the first 10 are frozen at some stations

Appendix 3 presents the overview of the scientific investigations which should be carried out during BESS-autumn. Appendix includes monitoring components, what kind of gear different sample takes, variable measures and outputs from these data.

A suggestion for a joint Norwegian-Russian monitoring program

The monitoring program aimed to monitor status of and changes in the Barents Sea Ecosystem should include surveys conducted in different seasons, reflecting the main processes (important oceanographic and biological processes). The adequate temporal and spatial resolution is important for detecting changes and monitor key processes and status of important ecosystem components. Therefore, the monitoring of the Barents Sea should include all seasons. The survey in winter (BESS-winter) might reflects spawning migration of key Barents Sea fish species and oceanographic shift (inflow of Atlantic waters during winter determine temperature condition during rest of the year). A second survey may measure the plankton bloom to determine the characteristics of the feeding season and should be carried out in spring-summer (The summer international ecosystem survey for the Nordic Seas, IESNS-summer). The third survey (BESS-autumn) may reflect the success of feeding season by annual production (biomass), and carried out in fall.

Four autumn-winter surveys (RAWS, JWS, NSCS and NGGS), target the estimation of stocks of the commercially important bottom fishes, as well as collect data of interspecies interaction and other ecosystem components. Cooperation with PINRO and joint planning, carrying out and reporting make the joint monitoring program effective with regards to resource use, survey equipment, data availability, use of assessment models and stock advice. Therefore we recommend conducting one ecosystem survey in winter (BESS-winter) instead of three surveys (RAWS, JWS, NSCS, and Table 8). The commercial stocks quota advice for the Barents Sea species will be based on BESS-winter and BESS-autumn. However, the RAWS is a main survey at Russian side and NGGS is one of three surveys at Norwegian side, providing Greenland halibut and redfishes data for stocks assessments. Therefore, we recommend joint conducting of ground gear survey along the continental slope (JGGS, see Table 8), which will provide the necessarily data stocks assessment and quota advice.

The ecosystem surveys of different extensions will provide the necessary data also for ecosystem status and support scientific research on stock dynamics, biodiversity, interactions and ecosystem processes. At IMR the BESS-winter and the BESS-autumn belong to and are funded by the research program “The Barents Sea”, while IESNS and NGGS belong to and are funded by the research program “The Norwegian Sea”. Use of all available surveys regardless of affiliation makes optimal use of recourses at IMR and better utilizing of surveys data. Therefore, we recommend using data collecting during IESNS to determine plankton bloom and the characteristics of the feeding season.

At present, there is no ICES WG dealing with integrated assessment in the Barents Sea, but IMR is now taking an initiative to establish such a group, consisting of scientists (mainly from IMR and PINRO) with diverse expertise, should analyse data/time series and present status report for the Barents Sea and give recommendations for further investigations (see below).

This WG should meet during January-February (in the year after the survey dealt with). Appendix 3 summarizes the sampling extent and the most important organisms in the two groups (commercially important (single stocks quota advice) and ecologically important). These data/estimates should be available for the institutes and ICES WGs as soon as possible.

Table 8. Existing and suggested monitoring. 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 days	- Demersal fishes: cod, haddock, Greenland halibut, redfishes	- Pelagic fishes: capelin, young herring, blue whiting - Interspecies interaction - Young groups of other commercial species	Oceanography
Data not used	IESNS summer	- Pelagic fishes: young herring, blue whiting	- Plankton	Oceanography
BESS-autumn (160 days)	BESS-autumn 160 days: NO-90days	- 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	

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

At the March meeting (Murmansk, Russia) the scientists from IMR and PINRO considered that changing the current monitoring of bottom fish species may seriously damage the quality of currents assessment for cod, haddock, Greenland halibut and redfishes, and therefore such changes of current monitoring to new optimized survey need to be analysed in detail and planned with caution. It was suggested to meet in January 2014 to: 1) propose a possible optimal design and timing of surveys 2) analyse possible consequences of change of monitoring 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. Therefore, this report recommends main suggestions for this survey, while the group will discuss and develop this survey in detail (survey design, timing, equipment, data products, and use of assessment models).

Objectives:

Primary objectives are fundamental for the stock advice:

– Cod and haddock
– Redfish and Greenland halibut

Secondary objectives are additional source for stock advice:

– Capelin
– Young of commercially important species

Additional objectives are source for other advice. Status and changes should be monitored for better understanding of ecosystem functionality.

– Marine environment

Area coverage

Due to the expansion of the cod distribution in recent years, large amounts of fish have been distributed outside the survey area. There is therefore a need for expanding the survey area, compared to the strata system defined in 1996 (Figure 8). The unknown part of young cod and haddock (1-2 years old) stay in the pelagic layer, and therefore should be covered also during survey with pelagic trawling. This also may help to scrutinizing and allocating the values to species or species groups in the pelagic layers. To obtain synoptically coverage 2 Norwegian vessels should participate during survey.

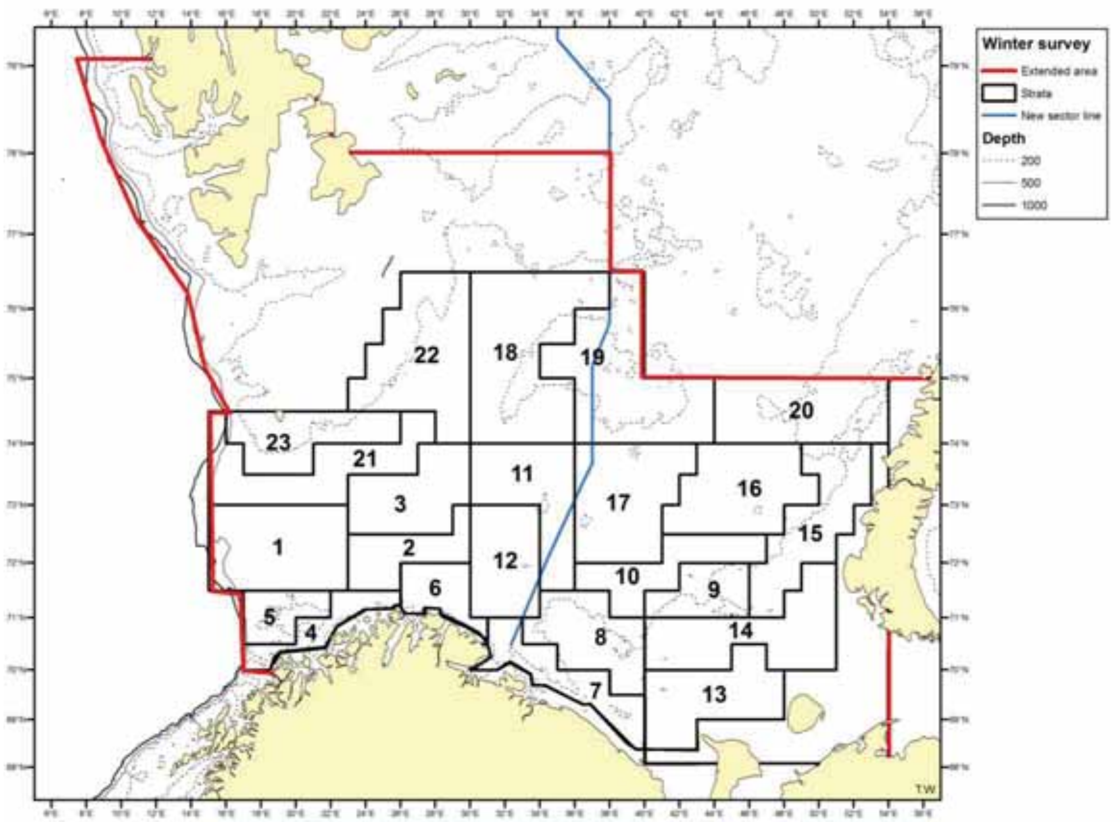


Figure 8. Extended survey area indicated by red line, while strata system indicated presence coverage.

Recommendations:
The new proposed area is shown in Figure 8. With this expansion there is also reason to open the station grid somewhat (about 30 n-mile distances in average, and possibly have a denser station grid in strata where there is normally higher fish densities). A total number of at least 250 valid bottom trawl hauls is required.

Additional pelagic trawling is recommended to cover the pelagic layer. Younger fish (1-2 years old of capelin, cod, haddock and redfishes, Eriksen et al., 2009) stay partly in the pelagic layer during winter, but the amount is unknown. Therefore, the pelagic component of cod, haddock and redfishes may be estimated by pelagic trawling and these data may be helpful for scrutinizing of acoustics. A total number of at least 50 pelagic trawl hauls is required, which means a total of 70 hauls including pre-determined pelagic hauls and pelagic hauls to capture pre-spawned capelin.

The associated total sailing distance would be about 9000 nautical miles. Therefore to obtain total coverage, participation of both Norwegian vessels and Russian vessels are needed and the total days at sea will be approximately 80 days and 70 days, correspondently.

Sampling coverage and extent

Primary objectives:
To achieve the necessary sampling for the primary objectives the BESS-winter should 1) cover the annual distribution of the total stocks of cod and haddock, 2) the stations per strata shall be sufficiently dense in the area with high variance of biomasses and 3) the biological sampling (fish lenght and weight, gonad weight, maturity and age) should be sufficiently frequent in order to make an abundance estimation that has an acceptable level of uncertainty. The biological sampling should be done according to Mjanger et al. (2011). Stomach samples from cod should be collected according to Mjanger et al. 2011 and analysed in lab (IMR) for estimating predation by cod.

Secondary objectives:
To achieve the necessary sampling for the secondary objectives the BESS-winter should 1) conduct pelagic trawling on large capelin schools echo registration, 2) pelagic trawling at pre-determined pelagic stations and 3) the biological sampling of capelin (fish lenght and weight, maturity and age) and young fish (length and weight of 30 specimens) should be sufficiently frequent.

Additionally objectives:
To obtain mapping of oceanographic condition during winter the BESS-winter should collect oceanographic data (temperature and salinity) from all pelagic stations.

Manning at Norwegian vessels and processing of samples:
The survey is manned by technicians/scientists with different expertise. Processing of catches taken by bottom and pelagic trawls is done directly on board by technicians skilled in fish taxonomy and biological sampling. Number of technicians at the fish lab on Norwegian

vessel may be 3 per shift, which corresponds 6 per vessel. No plankton experts are needed, while instrument people may process CTD-water samples on board. The total persons on board on Norwegian vessels might be 7 persons, including 6 technicians and 1 cruise leader.

Reporting:

A joint survey report should be completed as soon as possible and all collected data should be quality checked and be available in data bases at IMR and PINRO. The responsible scientists should deliver their contributions into the ICES WG, joint survey report and time series for SJØMIL database within 2 months after the survey, if data are available and properly quality checked.

Recommendations:

A survey report should include separate or combined maps for fish distribution. Additionally, number of samples collected and processed on board, and also number of samples which will be processed at lab on land. Further analyses will be done on ICES WG "The integrated assessment of the Barents Sea".

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

This acoustic survey carried out in April-June, and survey coverage includes also the Barents Sea (Figure 9). The aim of the survey was to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. PINRO cover the Barents Sea (area I), while IMR and other countries covers areas II and III.

This survey is joint survey and, therefore, all data are available all to participants.

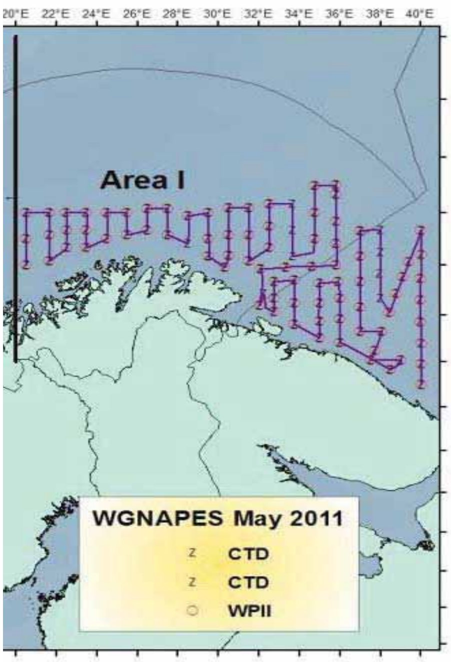


Figure 9. Cruise track for the International ecosystem survey in the Nordic Seas in April-June 2012.

Recommendations: The current and additional investigations may measure the plankton bloom to determine the characteristics of the feeding season. The additional investigations may be funded by "The Barents Sea program " at IMR.

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

Objectives

Primary objectives are fundamental for the stock advice:

- Pelagic fishes: (capelin and polar cod)
- The northern shrimp

Secondary objectives are additional source for stock advice:

- Pelagic fishes: (blue whiting and herring)
- Young of the year (commercially and ecologically important species)
- Demersal fishes: cod, haddock, Greenland halibut, redfishes, wolffishes
- Interspecies interaction

Additional objectives are source for other advice. Status and changes should be monitor for better understanding of ecosystem functionality.

- Pollution
- Marine environment
- Plankton community (alger and zooplankton)
- Pelagic community
- Demersal community (bentos and fish)
- Trophic interactions
- Biodiversity
- Marine mammals and seabirds

Area coverage

The last decades of climate change have resulted in most of Barents Sea being ice-free. The Ingvalsen's committee (2013) pointed out that "IMR should be an active partner in international efforts to investigate and monitor the physical and chemical state (hydrography, pollution, ocean acidification) in the Arctic Ocean and should propose collaborative multi-disciplinary projects on monitoring the state".

Recommendations:

A considerable amount of ship time is needed to cover the whole Barents Sea and simultaneously increased coverage into the Arctic Ocean. Therefore, to obtain the synoptic view of the whole Barents Sea, extent of occupation area of important commercial fish stocks towards north and east and map oceanographic condition towards Arctic Ocean:

The standard BESS-autumn should include the areas north of Norwegian and Murman coast and between east of Svalbard and west of Novaya Zemlya, corresponding to 75 days at sea with standard coverage within Norwegian coverage area (Figure 10). This is a main area aimed to deliver information from ecosystem stations to all survey objectives, and can be expended towards the north if distribution of important commercial fish stocks is wider.

The Arctic component should include the areas west, north and northeast of Svalbard, corresponding to 14 days with standard coverage. The investigation in this area is aimed at delivering data from ecosystem stations and additional shrimp stations to primary (the northern shrimps) and other objectives. The area may be extended northwards to study oceanographic condition towards the Arctic Ocean and therefore needs extra time.

Survey design

Survey design based on a combination of regular sampling, mapping spatial distributions of various ecosystem components, and denser sampling in capelin area and random bottom stratified sampling in shrimp area is ideal (Figure 10). All ecosystem stations and stations belonging to special investigations should be coded differently in the data bases.

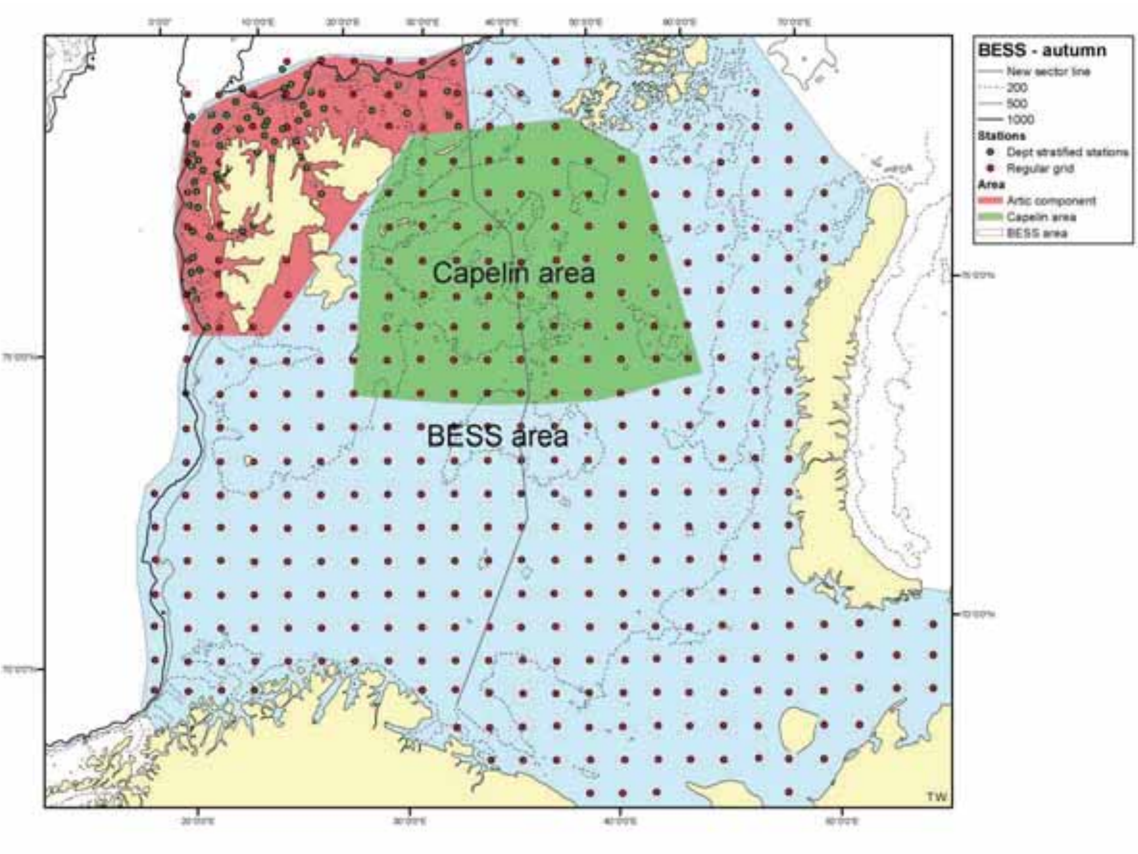


Figure 10. Map of the standard BESS-autumn survey.

Sampling coverage and extent

Overview of the scientific investigations carried out during the joint ecosystem survey in the Barents Sea are given by Michaelsen et al. 2011 (Appendix 4) and presents component monitored, gear used, samples taken, variable measured and application for these.

Primary objectives

To achieve the necessary sampling for the primary objectives the BESS-autumn 1) should cover the annual distribution of the total stocks of capelin, polar cod and shrimps within the Barents Sea, 2) the survey tracks should be sufficiently dense in the capelin area and have a sufficient number of station in the main shrimp area and 3) the biological sampling (lenght, weight, maturity and age) should be sufficiently frequent in order to make an abundance estimation that has an acceptable level of uncertainty. The consequences of different coverage on uncertainty level in the capelin assessment will be discussed in the paper, "Uncertainty properties of the Barents Sea capelin abundance estimate" by Tjelmeland, Gjøsæter, and Subbey, presented at The 16th Russian-Norwegian Symposium "Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology", Sochi, Russia, 11-14 September 2013.

When planning and carrying out the survey the following should be taken into account:

- A regular sampling, covering the entire Barents Sea, including the "capelin area" to obtain species- and size distribution of fish in the different depth and water layers, as well as to get samples for determining age-, sex-, maturity- and weight-composition of all target species caught. The spatial distribution, length, weight and age composition of immature capelin should be covered by regular sampling.
- A denser acoustic sampling in the capelin area give an appreciable contribution to the mean s_A in each square, a correct species identification, and adequate biological samples for necessary population estimations. This area is mostly occupied by mature capelin, which is fundamental for quota advice. To obtain the denser acoustic sampling within capelin area need 3 days extra.
- Appropriate time within the capelin area should be 2 weeks for standard coverage and 3 days for the denser acoustic sampling. The area coverage shall be performed during the second part of September. The trawling on registration of pelagic fish schools has highest priority and therefore will time for other investigations in this area have lower priority. Beside this, necessary time shall be given for trawling on echo-registrations of pelagic fish schools also outside this area during the whole survey.
- On a multi-vessel survey it is vital that acoustic data are interpreted in the same categories and groups on all participating vessels to facilitate easy exchange and joint interpretation of the results. Cruise leaders on all participating vessels should have good enough experience with scrutinising acoustics since stock size estimates are based on acoustics and trawl data.
- At present, the BESS-autumn is the only survey where data are collected for use in the assessment of the northern shrimp stock in the Barents Sea. In addition to regular sampling in the entire Barents Sea there is also need for additional shrimp station within the Arctic component (Figure 10). The biological investigations on the shrimp in the catch should also have the necessary level of detail to adequately resolve the demography of the stock. The northern shrimp sampling and stock assessment will be evaluated in 2013 at IMR and therefore a new sampling will be implemented from 2014.

– To monitor the Barents Sea ecosystem the Arctic component should be coordinated with main BESS-coverage and additional investigation of oceanography and plankton community may not influence timing and coverage of these stations mentioned above.

Secondary objectives

– Pelagic fishes: (blue whiting and herring) and young of the year (commercially and ecologically important species)
  A regular sampling by pelagic trawling, often called 0-group trawling, is performed in order to obtain species- and size distribution of fish in pelagic layers, as well as to get samples for determining age-, sex-, maturity- and weight-composition of the adult species and length for young of the year.

Recommendations:
An optimized sampling of 0-group fish may involve a reduction from 100 to 30 specimens per sample. The sampling effort will be discussed in the paper "Evaluation of the sampling strategy for the Norwegian-Russian 0-group component of the ecosystem summer survey", by M. Pennington, presented at The 16th Russian-Norwegian Symposium "Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology", Sochi, Russia, 11-14 September 2013.

- Demersal fishes: cod, haddock, Greenland halibut, redfishes, wolffishes: A regular sampling by bottom trawling is performed in order to obtain species- and size distribution of fish living near the bottom, as well as to get samples for determining age-, sex-, maturity- and weight-composition and weight of gonads for the target demersal fishes.

  At present there is an ongoing evaluation concerning use of data from BESS autumn in the assessment of the Greenland Halibut stock. Such an inclusion would involve more detailed sampling of Greenland Halibut.

- Species interaction
  In order to monitor species interactions, fish stomachs are sampled regularly during the BESS-autumn. The sampling strategy for cod is 1 stomach pr 5 cm length group while for capelin and polar cod it is the first 10 fish at all stations where biological samples are taken of cod, capelin, and polar cod.

Recommendations: The stomach sampling have been evaluated and reduced from ca. 2000 to 1000 (Norwegian side) and from ca 5 000 to 2 000 (Russians side) (see Table 9). The sampling processing will be further evaluated and discussed in the paper "30 years of stomach sampling and consumption calculations for Barents Sea cod – lessons learnt and the way forward", by B. Bogstad, presented at The 16th Russian-Norwegian Symposium "Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology", Sochi, Russia, 11-14 September 2013.

Additional objectives

- Pollution

  Every third year (2012, 2015 etc.), IMR carries out an assessment of the antropogenic impact on marine environment thorough investigations of the levels of organic pollutants, metals/GS (grain size)/TOC and radionuclides in sea water, sediments and marine biota in the Barents Sea. For more information see “Sampling manual”.

- Marine environment

  To observe the spatial and temporal oceanographic changes, water temperature and salinity are regularly measured as depth profiles covering the total area and along the fixed sections. The oceanographic depth profiles are made before or after trawl stations.

- Plankton community

  Sampling of water bottles for determining phytoplankton densities are carried out at pre-determined stations during the survey (ca 50-70 trawl station) and at pre-determined stations along the fixed transects. In addition a phytoplankton net is towed vertically in the upper 30 m at some selected stations.

The regular zooplankton sampling is made by WP2 plankton nets on Norwegian vessels and by Juday net on Russian vessels. Additionally, mesozooplankton sampling is carried out with the MOCNESS at selected stations (ca 1haul/station per day), with “Harstad” trawl at each trawl station, and sporadically with the new Macroplankton trawl on Norwegian vessels, and by BR plankton net attached to the bottom trawl on Russian vessels. Table 9 shows ships time used for different investigations, including plankton.

Recommendations: Today the plankton (phyto-, macro- and mesozooplankton) sampling takes 1/3 of the total BESS-autumn survey time available for investigations. Sampling of plankton therefore needs to be optimizing to make the total sampling during the survey more effective. Therefore, we recommend the following monitoring which will use less time and get more data available:

- WPII used at every second ecosystem station (bottom – 0m) and MOCNESS/Multinet used at every second ecosystem station. The sampling provides very important information for 1) scrutinizing of acoustic recording and 2) vertical distribution of plankton. WPII-hauls (bottom-0m and 100-0m) should be made if MOCNESS/Multinet cannot be conducted effectively due to technical reasons.
- “Macroplankton trawl” is conducted only when echo registration shows dense concentration of krill.
- Macroplankton from “Harstad” trawl should be processes as samples from “Macroplankton trawl”

Additionally, scientists from IMR and PINRO should discuss use of joint equipment and procedures to make data comparable. Russian vessels can lend MOCNESS/Multinet for use at Russian parts of surveyed area.

- Pelagic community

  A regular sampling by pelagic trawling, often called 0-group trawling, includes analyses of species- and size distribution of other fishes (not mentioned above), often called the small-sized fishes in pelagic layers.

Recommendations: The sampling of important biological information about the physical condition of the fish (parameters such as weight and length) of these fish species may be reduced to 30 per station. Such a reduction of specimen's measurements will make more effective the total sampling during survey. The sampling effort will be discussed in the paper "Evaluation of the sampling strategy for the Norwegian-Russian 0-group component of the ecosystem summer survey", by M. Pennington, presented at The 16th Russian-Norwegian Symposium "Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology", Sochi, Russia, 11-14 September 2013.

– Demersal community

  A regular sampling by bottom trawling, obtains species- and size distribution of non-commercial demersal fishes per station. Invertebrate and benthos, as well as number of individuals and total weight of each bentos taxon are also obtained per station.

Recommendations: The same recommendation as above for fish. Identification and measures of benthos from the bottom trawl might be reduced to every second year, while in the other years they might be discharged without any type of identification. The data on benthos (quality and effort) should be evaluated.

- Trophic interactions

  The monitoring of stomach samples of other fish species than mentioned above are only carried out on Russian vessels. Analyses of fish stomachs are performed on board by experts. IMR have planned to start an extensive sampling program to map trophic interactions in the Barents Sea in 2015 if funding becomes available.

Recommendations: The measure of benthic-pelagic coupling will involve further investigations than what is done today. Isotop analyses of important species (vertebrates and invertebrates), sediment analyses, and sedimentation in the water column will give important information in understanding the function and mechanisms of the Sea. Special surveys dedicated for this purpose might be a solution.

- Biodiversity

  A regular sampling of all organism taken by pelagic and bottom trawl, provides species- and size distribution of all fishes. Abundance or biomass of ecologically important species, belonging to different biogeographic groups (see Appendix 5) is estimated annually. Identification and measurements of benthic species from the bottom trawl have mostly been done by Russian experts. Abundance or biomass for ecologically important bentos communities (see box 4) is monitored and estimated annually if staffing is satisfactory (see “Manning at Norwegian vessels”).

Recommendations: In order to monitor biodiversity in fish biological samples (lenght and weight only) 30 specimens per species are sampled at all ecosystem stations by standard equipment.

– Additional fish biodiversity investigations based on depth stratified sampling around Svalbard might be covered each third year. The monitoring of fish communities will be discussed in a paper “The Barents Sea ecosystem survey: fish assemblages in the Svalbard sub-area” by Høines et al., presented at the 16th Russian-Norwegian Symposium “Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology”, Sochi, Russia, 11-14 September 2013.

– Benthos investigation should be carried out every year, but since IMR lack benthos expertise, additional funding will be required to hire Russian experts. These will allow for annual identification and measures of benthos from the bottom trawl, as well as training Norwegian technical personnel.

– Marine mammals and seabirds
  To monitor marine mammal and seabird distribution (species and numbers observed) these species are routinely recorded onboard the Norwegian and Russian vessels by visual observations.

Recommendations: In order to monitor abundance and distribution of sea mammals and seabirds, counting by experts should be continued in future surveys, and the method and protocols to use should be agreed on by Norwegian and Russian experts.

Reporting

A joint survey report should be completed as soon as possible and all collected data should be quality checked and be available in data bases at IMR and PINRO. It is important that data are processed and reported during, or as soon as possible after the survey. The responsible scientists should deliver their contributions into the joint survey report and time series for SJØMIL database within 2 months after the survey, if data are available and properly quality checked.

Recommendations: A survey report should include separate or combined maps for each investigation(s) which were done during the survey. The number of all types of stations should be reported, as well as number of samples collected and processed on board, and number of samples which will be processed at lab on land. The biomass/abundance of the most important organisms (Boxes 2-5) should be calculated and together with parameters for important processes presented in the survey report. Further analyses will be done on ICES WG “The integrated assessment of the Barents Sea”.

Time consumption by different investigations

BESS-autumn is the most comprehensive survey at IMR and PINRO. The total ships time (days at sea) has varied between years, and was highest in 2005 (228 days at sea) and lowest in 2010 (127 days at sea). The days-at-sea contribution from IMR and PINRO varied between years. The contribution from both institutions was similar during 2004-07, the PINRO's contribution was above 70% in 2008, but has since then decreased to 34%. Michalsen et al. (2011) suggested that for the BESS-autumn, the survey effort should be maintained at the 2005-2007 level (150-200 ship days) and the necessary days-at-sea could increase, if decisions are made to expand the cruise.

However, simultaneously with the decreasing of ship time, the surveyed area has increased. The determination of a new Norwegian-Russian sea-boarder resulted in that Russia got more area under own jurisdiction. With increasing ice-free areas both IMR and PINRO has therefore increased surveyed area towards the Arctic Ocean during recent years.

Simultaneously the number of other tasks and stations, collecting data belonging neither to primary or secondary objectives has increased. Therefore ships time use to take these stations has increased has been done at the expense of trawl stations (Table 9, Figure 11 and 12).

Investigations	2004			2005			2006			2007			2008		
	NO	RU	Tot	NO	RU	Tot	NO	RU	Tot	NO	RU	Tot	NO	RU	Tot
Days at sea (ship)	101	114	**215**	121	107	**228**	105	99	**204**	106	100	**206**	139	48	**187**
CTD	488	412	**900**	439	342	**781**	284	324	**608**	293	354	**647**	280	191	**471**
Algae net			**0**	32			**58**			61			35		
WP2 hauls	276		**276**	259		**259**	297		**297**	301		**301**	158		**158**
Juday hauls		203	**203**		41	**41**		181	**181**		141	**141**		67	**67**
MOCNESS	34		**34**	50		**50**	40		**40**	39		**39**	21		**21**
Macroplankton trawl			**0**	0											
BR		0	**0**		0			222			9			46	
Totalt plankton stations	310	196	**513**	341	117	**458**	395	156	**551**	401	163	**564**	214	113	**327**
Pelagic stations	196	284	**480**	319	154	**473**	210	272	**482**	205	289	**494**	229	130	**359**
Demersal stations	446	284	**730**	399	136	**535**	372	268	**640**	320	274	**594**	276	176	**452**
Total trawl stations trawl	642	568	**1210**	718	290	**1008**	582	540	**1122**	525	563	**1088**	505	306	**811**
Grabb/Aggassi		33	**33**	67	59	**126**	7 and 39	87	**124**	37/16	23	**76**	79/40		**119**
No of stomach sampled cod/haddock	1415	*1246/352*	**3013**	1880	1150/286	**3616**	1413	1387/496	**1416**	1059	2000/1153	**4212**	1387/463	1453/503	**3806**
No of stomach sampled capelin/polar cod		*245/0*	**245**	70	233/0	**303**	238	294/65	**597**	550/224	248/79	**1101**	388/168	235/147	**938**

Investigations	2009			2010			2011			2012		
	NO	RU	Tot	NO	RU	Tot	NO	RU	Tot	NO	RU	Tot
Days at sea (ship)	59	99	**158**	78	49	**127**	92	52	**144**	100	52	**152**
CTD	250	219	**469**	272	217	**489**	215	224	**439**	213	234	**447**
Algae net	38			65			71			62		
WP2 hauls	353		**353**	339		**339**	221		**221**	325		**325**
Juday hauls		91			105	**105**		113	**113**		134	**134**
MOCNESS	0			25		**25**	16		**16**	13		**13**
Macroplankton trawl				16		**16**	25			11	13	
BR		96			32			15				
Totalt plankton stations	391	187	**578**	445	137	**582**	333	128	**461**	411	147	**558**
Pelagic stations	259	130	**389**	245	120	**365**	287	130	**417**	252	126	**378**
Demersal stations	201	176	**377**	152	181	**333**	276	184	**460**	258	198	**456**
Total trawl stations trawl	460	306	766	397	301	**698**	563	314	**877**	510		**510**
Grabb/Aggassi	22		**22**		8	**8**		17	**17**	18	49	**67**
No of stomach sampled cod/haddock	1167	3117/964	**5248**	962	1951/543	**3456**	1097	1314/503	**2914**	958	1782/527	**3267**
No of stomach sampled capelin/polar cod	429/347	177/126	**1079**	250/182	225/153	**810**	169/140	432/268	**1009**		450/400	**850**

Table 9. Number of stations taken during BESS-autumn 2004-2012. NO shows the stations taken by Norwegian vessels, and RU –the stations taken by Russians vessels. Days at sea are taken from survey reports, and number of other stations/samples from data bases.

Recommendations: decreasing ship time, increasing surveyed area and an increased amount of other tasks have had a negative influence on the quality of collected data and have impacted the working conditions on board negatively. It is therefore recommended that the leaders of IMR and PINRO should evaluate and decide a priority list for the monitoring. This list has to be taken into account in case future budget and time allocated to the BESS is inadequate. To obtain the standard coverage with standard extent BESS-autumn needs 90 days, where 75 days are restricted to main area and 15 days to Arctic component. If decisions are made to expand surveyed area towards the Arctic Ocean the necessary days-at-sea should increase.

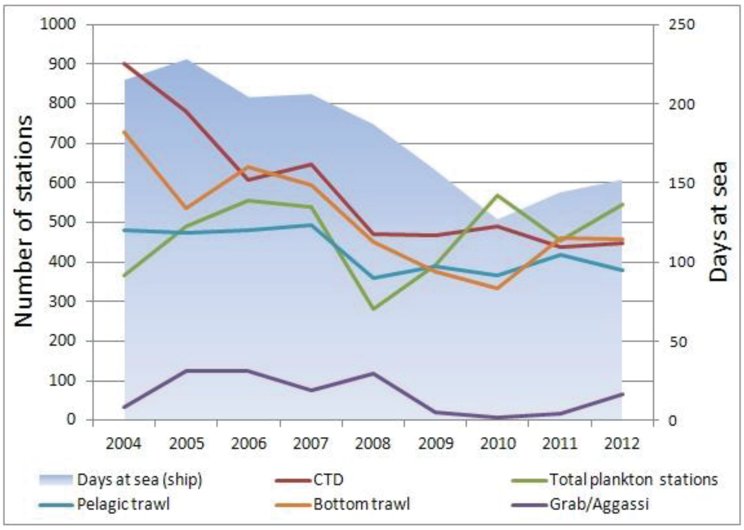


Figure 11. Total days at sea, and number of different stations, taken during ecosystem surveys 2004-2012.

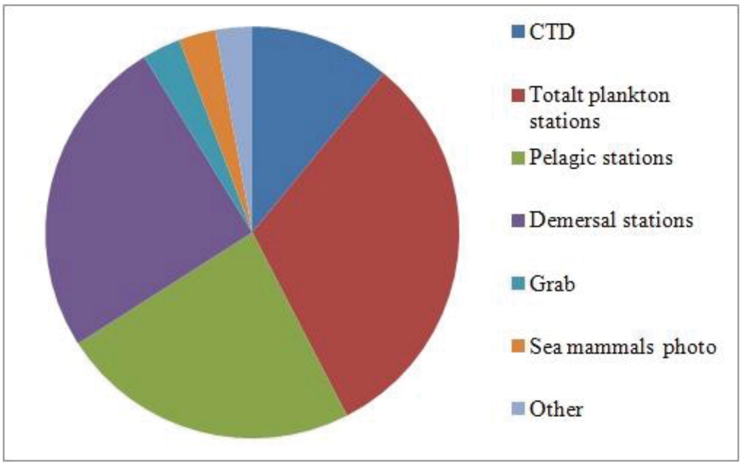


Figure 12. The averaged ships time use for different investigations during BESS-autumn 2004-2012.

During the BESS-autumn survey, the following equipments are used to collect an extensive amount of ecosystem data:

- CTD water sampler collects temperature, salinity, nutrients and chlorophyll *a*.
- Algae net collect phytoplankton.
- WP2 (Norwegian vessels) and Juday (Russian vessels) collects zooplankton. MOCNESS-mesozooplankton, and BR plankton net (Russian vessels) and macroplankton trawl (Norwegian vessels, often called krill trawl) - macroplankton.
- Pelagic trawl collects organisms in the upper (0-60m) pelagic layers (adult and young pelagic and bottom fish, euphausiids, hyperiids and jellyfish). The pelagic trawl is also used in targeted trawling (not quantitative) to get samples connected to acoustic surveying.
- Bottom trawl collects organisms (demersal fishes and invertebrates, including the northern shrimp) near the bottom and 5 m above.

Therefore, pelagic and bottom trawls are most important equipments for achieving both primary and secondary objectives, while other equipments are most important for achieving additional tasks. The surveyed area increase and number of stations should also increase, but we observed a decrease in number of trawls hauls, especially bottom hauls during the period 2004-2012.

Although trawls are most important equipments, use of ship time for other equipments was higher than for trawls during last three years, contrary to the important objectives (Figure 11). Therefore, an inclusion of other investigations should be evaluated and preferably reduced or moved into other surveys.

In recent years the sailing speed was reduced from 12 to less than 10 knots, because 10 knots is an economic speed for the vessels. In 2004 the sailing time during survey was 1/3 of all available time, while in 2010 and later the sailing time was ½ time of all available time. This means that Norwegian vessels used 20 % more time to cover the same area than before and had reduced time for investigations. This reduction of vessels speed was not taken account of for planning and or funding of BESS-autumn.

Recommendations:

- Number of trawl hauls should be maintained at the 2005-2007 level (380 pelagic and 600 bottom hauls) and this necessary increase of stations should occur in the main capelin, cod, haddock, Greenland halibut and redfishes areas, corresponding to ca.180 days at sea, and 90 days for the Norwegian parts.
- The main capelin area is very attractive area for many tasks (plankton, bentos and marine mammals), and therefore with increasing number of stations delivering data to additional objectives needs increasing of time there (3 weeks are needed to obtain the standard sampling within the Norwegian coverage area of "capelin area").
- Ship time used for other equipments than trawls, should be reduced or more days at sea should be added. Speed should be increased to 12 knops, if weather allows, which would lead to more effective use of survey time.
-

Manning at Norwegian vessels and processing of samples

Diverse investigations during survey are manned by technicians/scientists with diverse expertise.

CTD-stations including water samples on board do not need special expertise and are usually made by instrument people. However, further analysis or preservation of water samples other than those used for calibrating of the conductivity censor of the sonde, demands specialists in various fields (chemistry, biochemistry, and phytoplankton or zooplankton biology).

Processing of algae and other plankton net and macroplankton trawl needs experience in plankton taxonomy, and usually 2 persons per vessel are devoted to this work during the whole survey. These experts collect and preserve plankton samples, while full processing of samples will be done in the lab at IMR. During the period 2005-2012 the cost for processing of plankton samples in lab varied between 200 000 and 475 000 NKr, with average of 315 000 NKr annually. Therefore the cots for collecting and processing of plankton samples should be seen in the context both of costs of collecting the field materials and cost of their processing in the lab.

Processing of catches taken by pelagic and bottom trawls is done directly on board by technicians skilled in fish taxonomy and biological sampling. Number of technicians at the fish lab on board varied from 4 to 8 persons. These technicians process all biological samples of fish (lenght, weight, sex, maturity, age, and others), takes stomach samples, age determinate otoliths and process shrimp samples (sex, stage, length of carapace). During recent four years the fish lab was manned by 6 fish experts and one/two benthos expert(s) (one/none Norwegian and one Russian). The Russian benthos experts participated on board on Norwegian vessels and processed (species identification) almost all benthos samples, and these experts were funded by external projects. Therefore, the cost to process the benthos samples are not included in the BESS-autumn budget.

All fish, shrimps and benthos samples are processes on board, except stomach samples which are frozen and processed at the lab at IMR. During the period 2005-2012 the cost for processing of stomach samples at lab varied between 200 000 and 340 000 Nkr, with average of 270 000 NKr annually.

During the surveys marine mammals have been observed. Participation and funding of observers varied between vessels and years. The recent years "Ecosystem survey" project funded also sea mammal observers.

Seabird observers have participated in the surveys for a number of years (normally 1 person per boat), but these have been funded by an external project ("Seapop") organized by the Norwegian Institute of Nature Research (NINA).

Recommendation: With reduction of length measurements of 0-group fish and non-commercial fish species the number of technicians may be reduced from 4 per shift, corresponding 8 per vessels to 3 per shift, corresponding 6 per vessels.

- To continue the benthos investigation every year, we recommend that every second year a full processing involving Norwegian and Russian expertise, and the other year a reduced processing done by Russian experts on the Norwegian boats.
  - Increasing of MOCNESS/Multinet stations will increase amount of samples and therefore number of technicians should be increased to 2 per shift, corresponding 4 per vessels or less 3 per vessel.
  - Manning of Arctic component should be adapted to investigations. Number of ecosystem stations is reduced and therefore number of fish experts may be reduced. The most of stations are "shrimp" stations, and therefore needs shrimps experts. Additional plankton investigation will need plankton experts for collecting and processing of samples.

Recommendations for conducting BESS-autumn at IMR

- Coordination, planning, implementation and reporting are based on highly functional international collaboration between Norway and Russia. PINRO should be involved in the whole process to avoid problems with survey implementation.

- Comprehensive spatial coverage and adequate resolution needs 90 days at sea, and adequate manning (6 persons at fish lab, 4-3 persons at plankton lab, 2 sea mammals and 1 sea birds observers on board on each Norwegian vessel, and 1 extra pelagic person in “capelin” area, and 1 Russian coordinator on board on one Norwegian vessels).

- August-September is optimal seasonal timing for covering maximum distribution of key components, occurrence of both immigrating and local species, and period of least ice coverage.

- The data products (row data, maps, survey report, assessment outputs/reports) should be available as soon as possible after the surveys.

- Involving hired vessels might do planning and carrying out complicated, and data quality might be worse due to different equipment use and less experience with standard equipment. Therefore, use of hired vessels should be avoided.

Joint Norwegian-Russian autumn ground gear survey at the continental slope (JGGS)

At the March meeting (Murmansk, Russia) the scientists from IMR and PINRO agreed that changing the current monitoring of the bottom fish species may seriously damage the quality of current assessment for cod, haddock, Greenland halibut and redfishes, and therefore such changes of current monitoring to new optimized survey need to be analysed in detail and planned with caution. PINRO have only one survey (RAWS) which deliver the nessessary data for obtaining swept area abundance indices by length (and age) for Greenland halibut, and therefore Joint Norwegian-Russian autumn ground gear survey at the continental slope (JGGS) may be a way to go. It was suggested to meet in January 2014 to: 1) propose a possible optimal design and timing of surveys 2) analyse possible consequences of change of monitoring the bottom fish stocks on their assessments and 3) propose a transition plan for current surveys to new survey(s) if it will be found to be necessarily.
Therefore, we recommend coordinating Norwegian and Russian effort to carry out JGGS. Detailed suggestions for this survey, while the group will discuss and develop this survey in detail (survey design, timing, equipment, data products, and use of assessment models).

General and specific recommendations for IMR

Recommendations for funding and organising the monitoring

Organising and conducting ecosystem surveys demands a tremendous effort: planning, carying out, data processing and reporting. Both BESS-autumn and NRWS have been organized and financed in various ways at IMR (see above). Therefore, we recommend that each survey is organized in one project, lead by a scientific coordinator, leading a team including scientific and technical expertise. In addition, a committee should coordinate the total monitoring activity in the Barents Sea. This committee should be lead by the program leader, leading a team including the scientific coordinators for the various surveys. We also recommend a stable regulatory framework, securing that the monitoring program is carried out according to long-term plans.

Our experience is that team organisation is more appropriate when coordinating BESS-autumn since planning of comprehensive surveys is time-consuming and needs detailed expertise about investigations involved. A standard plan for BESS-autumn survey is suggested in this report and therefore planning of survey may take less time and decrease cost in the future. Our recommendation for the funding and organisation of BESS-autumn:

- One project lead by one scientific coordinator. The scientific coordinator should have in-depth scientific experience with BESS-autumn, and should be responsible for coordination of planning, implementation and reporting.
- The team is consisting of experts who are responsible for coordination and implementation of their own parts of investigations and reporting.
- One technical coordinator is focusing on technical planning and coordination of activities/vessels during survey. Tech. coordinator should be experienced with planning and carrying out of surveys.
- Coordinators (scientific and technical) should be funded by approximately 300 hours each annually, while experts by 50-100 hours, depends of investigation extent.
- All expenses related to a survey, including the planning, working up of samples after the survey, and reporting, should be included in the project.
- Our experience with the funding and organisation of NRWS is that project organisation is more appropriate to coordinate BESS-winter since the survey involves fewer investigations. The standard plan for BESS-winter survey will be discussed and presented by the joint working group and further planning may take less time and decrease cost at land in future. Our recommendation for the funding and organisation of BESS-winter:
- One project lead by one scientific coordinator. The scientific coordinator should have in-depth scientific experience with BESS-autumn, and should be responsible for coordination of planning, implementation and reporting.
- If needed one technical coordinator may focus on technical planning and coordinating of activities/vessels during survey. Tech. coordinator should be experienced with planning and carrying out of surveys.
- The team is consisting of experts who are responsible for coordination and implementation of their own parts of investigations and reporting.
- All expenses related to a survey, including the planning, working up of samples after the survey, and reporting, should be included in the project.

Organisation of the monitoring program should be coordinated by the program leader. We recommend that a committee lead by the program leader and including survey coordinators (BESS-winter and BESS-autumn) and one or more ICES WG member(s) should plan yearly monitoring of the Barents Sea. The committee may change extent of investigations, include or exclude investigation(s) or move them to other seasons and surveys.

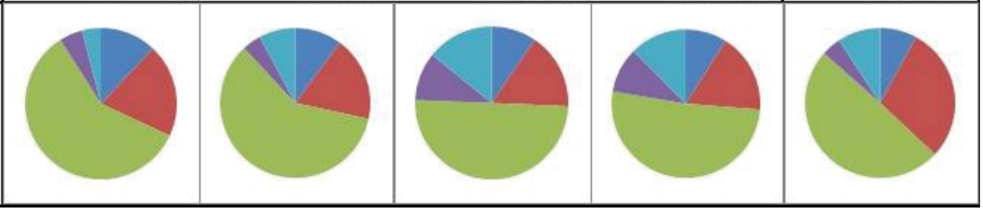
The cost for a suggested monitoring in the Barents Sea is given in Table 10 and more detailed overview for BESS-autumn in Table 11. Table 10 gives an overview of “Costs at sea” for manning the survey, “Cost at land” which are related to planning and reporting, and “Cost for sample processing” which is related to processing of stomach and plankton samples in lab. BESS-winter and BESS-autumn costs are calculated based on suggestions discussed above and 2013 cost rates. It is difficult to get cost for JGGS since that survey was not discussed in detail. IESNS may be improved by including some additional tracks and therefore approximate cost for this was estimated.

Table 10. The cost for a suggested monitoring in the Barents Sea.

BESS-Autumn	**2013**	**BESS-Autumn 2014**
Cost at land	2 060 240	2 075 000
Cost at sea	12 366 330	12 984 750
Cost for sample processing	1 043 000	1 032 875
TOTAL COST FOR RESEARCH PROGRAM BS	15 469 570	16 092 625
BESS-winter	**2012**	**BESS-winter 2015**
Cost at land	1 181 244	1 000 000
Cost at sea	2 327 214	5 320 000
Cost for sample processing	509 000	600 000
TOTAL COST FOR RESEARCH PROGRAM BS	4 017 458	6 920 000
NSCS	**2012**	
cost at land	423 622	Survey do not include in the monitoring
cost at sea	685 688	
Other cost	326 196	
TOTAL COST FOR RESEARCH PROGRAM	1 435 506	
NGGS	**2011**	**JGGS 2015**
cost at land	814 439	Our suggestions to conduct joint survey
cost at sea	304 935	
Other cost		
TOTAL COST FOR RESEARCH PROGRAM BS	1 119 374	~ 1000000
IESNS	**2012**	**IESNS 2014**
cost at land	Norwegian sea research program owned survey	
cost at sea		
Other cost		~ 500000
TOTAL COST FOR RESEARCH PROGRAM BS		~ 500000
TOTAL COST FOR RESEARCH PROGRAM	**22 041 908**	**23 012 625**

Table 11. The cost for a suggested BESS-autumn.

	2010	2011	2012	2013	2014
Cruise leader	787 656	799 200	918 000	1 011 200	855 000
Plankton	1 309 212	1 436 400	1 555 200	1 958 400	3 135 000
Fish/Shrimp/Bentos	3 874 416	4 696 160	4 801 680	5 814 900	5 343 750
Sea mammals	325 600	320 000	978 300	1 117 550	450 000
Other investigations	266 100	617 824	1 367 040	1 407 180	1 000 000
Totalt at sea	**6 562 984**	**7 811 872**	**9 343 520**	**12 366 330**	**13 984 750**



Recommendations for what equipment and gears that should be applied

Standardization of equipments and methods is vital for proper monitoring, and therefore we recommend that a set of survey manuals are made, updated and strictly followed during planning and carrying out of the surveys. All equipment should be standardized and calibrated. Alongside this standardization, time and money should be set aside for testing out new equipment and methods for future implementation in the monitoring activity.

Survey manuals are fundamental documentation for surveys equipment and processing. All equipments which are used on Norwegian and Russian vessels during the surveys are described above in this report. Survey manuals should be present for all surveys, updated by responsible persons and followed by cruise leaders and vessel crews.

During BESS-autumn survey in 2012, it was observed that pelagic trawls were not identical to specifications given in the manual. Length of cod end and number of panels varied between trawls and vessels. It’s difficult to find information when and why trawl panels and cod ends were changed. Therefore, this project included experts of fishing gear technology, who will continue to work with standardization of all survey equipment and update survey’s manuals. Further work needs funding.

Some of the equipments (Campelen, Harstad, and Macroplankton trawls) will be standardized, although additional improvements should be implemented between nations and boats and intercalibration should be undertaken to adjust for the confounding between area and boat effects since the same boats covers the same areas in most years (e.g. Russian vessel in the Russian zone).

In parallel with the standardization of equipment new sample techniques should be investigated. One component of the survey is mapping the upper pelagic zone using a standard sampling “Harstad” trawl towed with the headline at 0, 20 and 40 m, over a single 0.5 nm tow. All catch becomes mixed in a single cod end, and information on spatial distribution and species overlap within the hauls are lost. A new sample trawl in combination with a multisampling device should be developed/tested, which would improve the vertical resolution of the data. “DeepVision” stereo camera equipment was tested during BESS-august, August 2012. This equipment captures a continuous record of all organisms passing through the extension of the trawl. Individuals ranging from macro-plankton including krill, amphipods and jellyfish to 0-group and adult fish could be identified and measured in the images. Fine-scale patchiness and species overlap were documented both vertically and horizontally along the cruise track. We recommend further testing of this equipment to investigate whether this (or similar) equipment should be implemented in the future. The implications for further development optic equipment and refinement of sampling techniques will be discussed in the paper, "DeepVision: an in-trawl stereo camera makes a step forward in monitoring the pelagic community" by Shale Rosen, Melanie Underwood, Arill Engås and Elena Eriksen, presented at The 16th Russian-Norwegian Symposium "Assessments for management of living marine resources in the Barents Sea and adjacent waters - a focus on methodology", Sochi, Russia, 11-14 September 2013.

Recommendations for standardized data products

Sea2data and databases:

Huge amounts of data are collected during the ecosystem surveys. Most data will add to those from earlier surveys to form time series, while some data belong to special investigations conducted once or to projects of short duration. Another way of classifying data is distinguishing between joint data, i.e. data collected jointly by IMR and PINRO, and data collected by visiting researchers from other institutions, using the survey vessels as a platform for data collection without being part of the overall aim with this survey. Joint data are contained in the databases of both PINRO and IMR and are freely accessible to all inside the institutions

IMR is now developing a new data-infrastructure through the project S2D. Old databases are replaced by a new family of databases administered by NMD. Although the data are split on several databases, for instance one for acoustic data, one for biological data, another for physical and yet another for chemical data, they are linked through a common reference database and all data can be seen through a common user interface. At PINRO they are also planning to move their data into a new set of databases.. In addition to these institutional data repositories a joint database for some selected time series of aggregated data has been developed, called "Sjømil". At present this database is present at IMR and PINRO, and the IMR database is accessible to the outside world through a web interface http://www.imr.no/sjomil/index.html. This database is general and has data from many other monitoring programs and from other areas than the Barents Sea.

It is recommended that further development of S2D is undertaken in close cooperation with PINRO, with aim to develop standardized procedures for data exchange and a set of agreed methods and tools for stock size indices, distribution maps, and other standard data products.

Estimations methods:

The cost of monitoring is a significant part of the budget for IMR, and therefore research on survey methods and analysis to improve cost efficiency should be strengthened. Towards this goal we recommend that a multidisciplinary team of modellers and survey scientists be established to improve and coordinate IMR's survey monitoring programs, in close cooperation with the cruise planning committee. We further recommend that experimental studies be imbedded in any large monitoring survey to continuously improve survey efficiency and effectiveness. We propose that 10% of the survey time be allocated for experimental studies in addition to standard survey of 90 days-at-sea. Some suggested experiments are listed below:

- Assess the practicality of random sampling for age (would provide unbiased estimates of numbers at age without the use of age-length keys). Evaluate procedures with some proportionality to catch size (more samples from large catches) if age analysis of survey data demonstrate that composition by size and age is related to catch size.
- Start long-term experiments to improve estimates of precision of important abundance indices for systematic sampling. Need to build up data on spatial autocorrelation at finer scales than the survey grid size to support model-based estimation of variance.
- Experiment to test utility of sub-sampling of depths at 0-group surveys (random pick of depth-layer for tow at a station). Would provide information on biomass by depth layer, and reduce time at each station.
- Test of procedures for random sub sampling on board to examine if such random subsamples indeed are provided.

BESS-winter: The statistic-workshop in Bergen, January 2013, which was an integral part of the present project, considered two methods for estimating number of fish by age (standardized area-swept estimates) at each trawl station (primary sampling units), for use as input data to analytical age-based stock assessments. The preferred method ("best scientific practice") for estimating number at age depends on the survey design and sub-sampling methods for length and age. These methods and further analyses of possible consequences of change of monitoring the bottom fish stocks will be discussed in January 2014 by experts from IMR and PINRO.

BESS-autumn: The statistic-workshop (Bergen, January 2013) recommends using stratified mean of (jellyfish and krill) biomass per area swept, calculates standard errors and test the use of combined trawl and acoustic data. 0-group indices should be presented with confidence intervals in Survey Report. All estimators should be given with uncertainties.

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Appendix 1. The most ecologically important plankton and the optimal time for the monitoring.

Optimal time for coverage	Optimal timing / sub-optimal timing / limited information / impossible to cover / uknown	Coverage period: January 1 part	January 2 part	February 1 part	February 2 part	March 1 part	March 2 part	April 1 part	April 2 part	May 1 part	May 2 part	June 1 part	June 2 part	July 1 part	July 2 part	August 1 part	August 2 part	September 1 part	September 2 part	October 1 part	October 2 part	November 1 part	November 2 part	December 1 part	December 2 part	Input to the Barenta Sea monitoring
GROUP	Most important SPECIES																									
copepoda	*Metridia lucens*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing													**Covered area: whole Baretns Sea.**
copepoda	*Metridia longa*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing													
copepoda	*Calanus glacialis*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing													
copepoda	*Calanus hyperborus*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing													
copepoda	*Calanus finmarchicus*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							After survey biomass per watermasses (Atlantic, mixed and Arctic) and area estimated should be delivered. Biomass will be based on rought prossesing on board
copepoda	*Pareuchaeta norvegica*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
copepoda	*Pareuchaeta glacialis*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
copepoda	*Pareuchaeta spp.*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Onisimus nanseni*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Onisimus glacialis*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Gammarus wilkitzkiii*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Themisto abyssorum*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Themisto libellula*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
amphipoda	*Themisto compressa*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
euphausiacea	*Meganyctiphanes norvegica*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
euphausiacea	*Thysanoessa inermis*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							
euphausiacea	*Thysanoessa longicaudata*									sub-optimal timing	sub-optimal timing					Optimal timing	Optimal timing	Optimal timing	Optimal timing							After survey plankton sample prossessed at lab
euphausiacea	*Thysanoessa raschii*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
pteropoda	*Limacina helicina*									sub-optimal timing	sub-optimal timing	Optimal timing	Optimal timing			Optimal timing	Optimal timing	Optimal timing	Optimal timing							
pteropoda	*Limacina retroversa*															Optimal timing	Optimal timing	Optimal timing	Optimal timing							
Cnidaria	*Cyanea capillata*															Optimal timing	Optimal timing	Optimal timing	Optimal timing							
Chaetognatha:																Optimal timing	Optimal timing	Optimal timing	Optimal timing							

Appendix 2. **The most important fish species according to criteria decided above and optimal coverage periods for each of them.**

Family	Optimal timing / Sub-optimal timing / Limited information / Impossible to cover / Unknown	Coverage period: January 1. part	January 2. part	February 1. part	February 2. part	March 1. part	March 2. part	April 1. part	April 2. part	May 1. part	May 2. part	June 1. part	June 2. part	July 1. part	July 2. part	August 1. part	August 2. part	September 1. part	September 2. part	October 1. part	October 2. part	November 1. part	November 2. part	December 1. part	December 2. part	Optimal area coverage
Agonidae	*Leptagonus decagonus*/ Atlantic poacher		Unknown	Sub-optimal	Sub-optimal	Sub-optimal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	W, N, E, NW, NE, SE, Center
Ammodytidae	*Ammodytes marinus*/ Lesser sandeel	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	
Anarhichadidae	*Anarhichas denticulatus*/ Northern wolffish	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	E, W, NW, Center
	Anarhichas lupus/ Atlantic wolffish	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	S, W, NW, SE, Center
	Anarhichas minor/ Spotted wolffish	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	S, W, NW, SE, SW, Center
Clupeidae	*Clupea harengus*/ Atlantic herring	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Optimal	Optimal	Optimal	Unknown	Unknown	Unknown	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	S, W, N, E, C
Cottidae	*Triglops nybelini*/ Bigeye sculpin	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	N, NW, NE, E
	Triglops pingelii/ Ribbed sculpin	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	N, E, NW, SE
Cyclopteridae	*Cyclopterus lumpus*/ Lumpsucker	Unknown	Unknown	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limited	Limited	Limited	Limited	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	S, W, E, SW, NW, SE, Center
Gadidae	*Boreogadus saida*/ Polar cod	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Impossible	Optimal	Optimal	Optimal	Optimal	Optimal	Optimal	Sub-optimal	Sub-optimal	Impossible	Impossible	N, NW, NE, E, SE, Center
	Gadus morhua/ Atlantic cod	Unknown	Unknown	Optimal	Optimal	Optimal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	S, W, N, E, NW, SW, SE, Center

	Melanogrammus aeglefinus/ Haddock	S, W, NW, SE
	Micromesistius poutassou/ Blue whiting	S, W, SW, NW
	Pollachius virens/ Saithe	S, SW
	Trisopterus esmarkii/ Norway pout	S, W, SW
Osmeridae	*Mallotus villosus*/ Capelin	S, W, N, E, SE, NW, Center
Pleuronectidae	*Hippoglossoides platessoides*/ Long rough dab	whole BS
	Liopsetta glacialis/ Arctic flounder	SE
	Reinhardtius hippoglossoides/ Greenland halibut	W, N, slope, center
Rajidae	*Amblyraja hyperborean*/ Arctic skate	N, E
	Amblyraja radiate/ Thorny skate	NW, W, S, C
Scorpaenidae	*Sebastes marinus*/ Golden redfish	S, W, SW, NW
	Sebastes mentella/ Beaked redfish	S, W, N, Center
	Sebastes viviparus / Norway redfish	SW
Squalidae	*Somniosus microcephalus*/ Greenland shark	N, E

Appendix 3. Overview of the scientific investigations that should be carried out in the Barents Sea.

Ecosystem components to monitor, gear to use, samples to take, variables to measure and application for these are given in Michalsen et al. 2011, and adequate survey is shown in colours (1-BESS-Winter, 2- IESNS, 3-BESS-autumn and 4-JGGS).

Component monitored		**Sampling gear**	**Samples taken**	**Variable measured**	**Application**	**Surveys**
Currents	at stations and between stations	ADCP	-	Current vectors	Current fields, model input	1,3
Water masses	at stations	CTD, water sampler	water	Temperature, Salinity, Depth, Oxygen, Fluorescence, Light	Distribution of water masses, input to models	1,2,3
Nutrients	at stations	Rosette Water bottle System	nitrate, phosphate, silicate, nitrite in water	Nutrient levels	Mapping of nutrient levels	1,2,3
Pollution	Inorganic, organic and radioactive	Water sampler, box-corer, Demersal (Campelen 1800) and pelagic trawl (Harstad)	Water, sediment, tissue samples (fish)	Pollution levels	Mapping of pollution levels in the BS. Advice to Ministry of Environment/Fisheries	3
Phytoplankton	at stations and over sections	Algae net, water bottle samples, *in situ* fluorometer (on CTD, not on all ships). Termosalinograph with fluorometer (not on all ships)	-	Species composition and abundance, chlorophyll *a*, fluorescence,	Mapping of distribution, research, input to management plan	2,3
Zooplankton	at stations and over sections	**Sensor1**: Plankton net (WP2), MOCNESS, **Sensor2**: Krill, pelagic and bottom trawls	Plankton, dry and preserved (formalin) Macroplankton, wet/dry weight	Biomass, species composition and abundance Biomass, species composition	Mapping of distribution and biomasses, research, input to management plan	2,3

Target fish species						
Cod		**Sensor1**: Demersal trawl (Campelen 1800) **Sensor 2:** Echosounder (EK60)	Otoliths, Stomachs Acoustic recordings	Numbers, biomass, length, sex, maturity status, diet composition. Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports, predation mortality on capelin and shrimp	1,3
Haddock		**Sensor1**: Demersal trawl (Campelen 1800) **Sensor 2:** Echosounder (EK60)	Otoliths Acoustic recordings	Numbers, biomass, length, sex, maturity status, Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	1,3
Greenland halibut		**Sensor1**: Demersal trawl (Campelen 1800)	Otoliths	Numbers, biomass, length, sex, maturity status,	Assessment –ICES advice, internal IMR reports,	1,3,4
Redfish		**Sensor1**: Demersal trawl (Campelen 1800) **Sensor 2:** Echosounder (EK60)	Otoliths Acoustic recordings	Numbers, biomass, length, sex, maturity status, Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	1,3,4
Herring	Juveniles	**Sensor1**: Pelagic trawl (Harstad) **Sensor 2**: Echosounder (EK60)	Otoliths Acoustic recordings	Numbers, biomass, length, Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	1,3
Capelin		**Sensor1**: Pelagic trawl (Harstad) **Sensor 2**: Demersal trawl (Campelen 1800) **Sensor 3**: Echosounder (EK60)	Otoliths Otoliths Acoustic recordings	Numbers, biomass, length, sex, maturity status Numbers, biomass, length, sex, maturity status Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports	1,3
Blue whiting		**Sensor1**: Pelagic trawl (Harstad) **Sensor 2**: Echosounder (EK60)	Otoliths Acoustic recordings	Numbers, biomass, length, sex, maturity status Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	2,3

0-group fishes		**Sensor1**: Pelagic trawl (Harstad) **Sensor 2**: Echosounder (EK60)	Otoliths Acoustic recordings	Numbers, length Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	3
Polar cod		**Sensor1**: Pelagic trawl (Harstad) **Sensor 2**: Echosounder (EK60)	Otoliths, stomachs some years Acoustic recordings	numbers, biomass, length, sex, maturity status Vertical distribution, SA, TS	Assessment –ICES advice, internal IMR reports,	1,3
Other fish species monitored						
All pelagic and demersal fish species sampled		**Sensor 1**: Demersal trawl (Campelen 1800) **Sensor 2**: Pelagic trawl (Harstad) **Sensor 3**: Echosounder (EK60)	 Acoustic recordings	Length distribution, biomass Length distribution, biomass Vertical distribution, SA, TS	Ecosystem status reports (ICES, and joint IMR/PINRO), input to management plan, monitoring by-catch	1,3
Benthic decapods						
Deep-sea shrimp		Demersal trawl (Campelen 1800)		stage and length measurements	Assessment –ICES advice, internal IMR reports,	1,3
King crab		Demersal trawl (Campelen 1800)		Carapax width, sex	Monitoring, assessment (minor) internal reports	1,3
Snow crab		Demersal trawl (Campelen 1800)	Whole individuals	Carapax width, sex	Monitoring, assessment (minor) internal reports	1,3
Other benthos	All	Demersal trawl (Campelen 1800) Grab, beam trawl, cam-pod (video), epibenthic sledge	Formalin fixed samples to be analyzed in lab on land	Species, numbers, biomass	Habitat mapping, starting time-series, monitoring by-catch	3
Marine mammals All species		Observers	Visual observations	Numbers, species, calves/adults	Monitoring distribution, research, input to management plan	3
Seabirds						
All species		Observers	Visual observations	Numbers, species, juvenile/adults	Monitoring distribution, research, input to management plan	3

Appendix 4. The sampling extent and acceptable level for the most important organisms and groups.

Criteria family	Criteria	Unacceptable level, results cannot be deliverd	Sub-optimal level, acceptable for some results to be delivered	Desired/Optimal level, ensuring delivery of results
Quota advice - single stocks	*Gadus morhua*/ Atlantic cod	Biennial, only autumn, No length/weight/age samples, Only Norwegian or Russian sone	Reduced coverage. Two times every year. Winter: length/ weight/ age/sex, weight of gonads/ maturity/ diet composition. Autumn: length/ weight/age/sex, weight of gonads/maturity.	Two times every year. Winter: length/weight/age/sex, weight of gonads/maturity/diet composition. Autumn: length/weight/age/sex, weight of gonads/maturity/diet composition
	Melanogrammus aeglefinus/ Haddock	Biennial, only autumn, No length/weight/age/maturity samples, Only Norwegian or Russian sone	One time every year. Winter: length/weight/age/sex/maturity.	Two times every year. Winter : length/weight/age/sex, weight of gonads/maturity. Autumn: length/weight/age/sex/maturity.
	Mallotus villosus/ Capelin	Bienniall. Absence of length, weight, age or stomach samples. No trawling on registrations, Only Norwegian or Russian sone	One survey per year (autumn). Survey tracks too far apart or biological sampling too infrequent or total coverage too incomplete to map the distribution of capelin with acceptable uncertainty.	One survey every year for abundance estimation (autumn), with total coverage of capelin. Survey tracks sufficiently close in the main area of adult capelin and biological sampling sufficiently frequent to make an abundance estimation of capelin with an acceptable level of uncertainty. Additional survey in winter covering the spawning migration and overlap with main predators in time and space
	Clupea harengus/ Atlantic herring	Bienniall. Absence of length, weight or age samples., Only Norwegian or Russian sone	Every year. Autumn and length/weight/sex/age samples.	Two times every year. Winter: length/weight/age/sex. Autumn: length/weight/age/sex/maturity/special stage.
	Boreogadus saida/ Polar cod	Bienniall. Absence of length, weight, age or stomach samples. Only Norwegian or Russian sone	Covered every year: in autumn and length/weight/age samples. No stomach samples. Less than 10 twarling on registrations	Survey every year: in autumn and length/weight/age samples. Stomach analysis program. 15-20 trawling on registrations

Pollachius virens/ Saithe	Biennial. Absence of length, weight, age or stomach samples. Only Norwegian or Russian sone	Trawl and acoustic sampling covering the whole geographical distribution of the stock at least biennially (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas.	Trawl and hydro acoustics sampling covering the whole geographical distribution of the stock at least once a year (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas
Sebastes mentella/ Beaked redfish	Less than biennial survey frequency. Survey coverage not including the species distribution in the Norwegian or Barents Sea. Absence of length, weight or age samples.	Trawl and acoustic sampling covering the whole geographical distribution of the stock at least biennially (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas.	Trawl and acoustic sampling covering the whole geographical distribution of the stock at least once a year (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas
Sebastes viviparus / Norway redfish	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	Trawl and acoustic sampling covering the whole geographical distribution of the stock at least biennially (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas.	Trawl and acoustic sampling covering the whole geographical distribution of the stock at least once a year (Norwegian sea, slope, shelf and Barents Sea). Numbers/age/length by areas
Reinhardtius hippoglossoides/ Greenland halibut	No information on juvenile occurance	Bottom trawl stations in core area of distribution for juvenile Greenland halibut.	Bottom trawl stations for sampling of juvenile Greenland halibut in the whole known distribution area from North of Svalbard to Kara Sea every year. BESS-autumn and
Northern shrimp	Biennial, only biomass per station, no stageing/length measurements, only Norwegian or Russian sone	Annual, biomass/abundance per station, no stage/length measurements, ecosystem survey only, both Norwegian and Russian zones	Annual, biomass/abundance per station, sex/maturity stage/carapace length for a subsample of 250-300 inds from catches > 5 kg). A sample of up to 100 juvenile inds from juvenile (Hoita) bag. Limited sub sampling also on winter survey. Both Norwegian and Russian zones.
King crab	only number or weight	weight/length	Carapace length (from the right eye orbit to the notch at the rear of the carapace), sex (see drawings in the sampling manual), carapace age (see table in sampling manual) and presence/absence of external eggs

Other advice (assessment models, biodiversity, indicators etc)	Clupea harengus/ Atlantic herring	Biennial, No length/weight/age samples, Only Norwegian or Russian sone	Covered every year: in autumn and length/weight/age samples.	Survey every year: in autumn and length/weight/age samples. Stomach analysis program.
	Micromesistius poutassou/ Blue whiting	Bienniall. Absence of length, weight, age or stomach samples. Only Norwegian or Russian sone	Covered every year: in autumn and length/weight/age samples.	Survey every year: in autumn and length/weight/age samples. Stomach analysis program. 15-20 trawling on registrations
	Hippoglossoides platessoides/ Long rough dab	Bienniall. Absence of length, weight, age or stomach samples. Only Norwegian or Russian sone	Covered every year: in autumn and length/weight	Survey every year: in autumn and in winter: length/weight/age samples. Stomach analysis program.
	Northern wolffish	No spesies identification, redused coverage area.	Covered every year: in autumn and length/weight	Sampling during August-October, bottom trawl, weight and lenght measurements
	Atlantic wolffish	No spesies identification, redused coverage area.	Covered every year: in autumn and length/weight	Sampling during August-October, bottom trawl, weight and lenght measurements
	Spotted wolffish	No spesies identification, redused coverage area.	Covered every year: in autumn and length/weight	Sampling during August-October, bottom trawl, weight and lenght measurements
	Salmo salar/ Atlantic salmon	Biennial, No length/ weight/age samples, no stomach analysis, Only Norwegian or Russian sone	Sampling during fall, pelagic trawl, only lenght measurements	Sampling during winter and fall, pelagic trawl, weight and lenght measurements
	Cyclopterus lumpus/ Lumpsucker	Biennial, No length/ weight/age samples, no stomach analysis, Only Norwegian or Russian sone	Sampling during fall, pelagic trawl, only lenght measurements	Sampling during winter and fall, pelagic trawl, weight and lenght measurements
	Hydrography/water masses distribution/area	Biennial, No length/ weight/age samples, no stomach analysis, Only Norwegian or Russian sone	Winter or summer or autumn at oceanographic sections and reduced spatial coverage	To obtain the horizontal and vertical distribution of water temperature, salinity and nutrients in the Barents Sea: winter, summer and autumn at oceanographic sections: and surveys area surveys

	Spring bloom	Each third forth years	Covered every year: in mai	Survey every year: in June. Measurement of Chlorophyll a, fluorescence and organic
	Primary production/new production	biannual	only one period (May or autumn). Ad hoc use of CTD (e.g. attached to sampling gear) on most surveys	Two times every year (June and Autumn). Dedicated CTD stations. Measurement of standard physical/biological parameters (Fluorescence, Oxygen, nutrients) on all surveys.
	Plankton biomass/Size fractions	biannual	only one period (May or autumn). And only use of WP2.	Two times every year (May-June and Autumn), whole Barents Sea. Use of Mocness/Multinet
	0-group indices (abundance and biomass) of commercially important species	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	Every each year. Between August and October. Only within the core area, measurement of lenght, no otholits. Use of Harstad trawl	Sampling during the optimal coverage timing-second part of August - first part of September, full species identification, Lenght measurements of all species, and otoliths of some species for 0-group identification. Use of Harstad trawl. Whole Barents Sea
	Indices of non-target: small fishes	No registration of jelly fish, no weight, only winter	Every year (Autumn). Measurement of length and weight, no otholits. Use of Harstad trawl. Species identification to family level	Every year (Autumn), whole Barents Sea. Use of Harstad trawl. Measurement of lenght and weight. Species identification.
	Zoobentos biodiversity/Species richness	No species identifications	Every year: Autumn, whole Barents Sea processing: species identification, lenght measurements of some species	Each year: during autumn, whole Barents Sea, full species identification, Lenght measurements of all species
	Snow crab	No spesies identification, redused coverage area.	Sampling during autumn, bottom trawl, weight and lenght measurements	Sampling during winter and autumn, bottom trawl, weight and lenght measurements

Ecologically important components/processes	Flux	Biennial, Only Norwegian or Russian sone	Winter or summer or autumn at oceanographic sections	Winter, summer and autumn at oceanographic sections
	Water masses/Vertical structure	No environmental observations	Ad hoc use of CTD (e.g. attached to sampling gear) on most surveys	Dedicated CTD stations. Measurement of standard physical parameters on all surveys.
	Sea ice	no currents measurments, ADSP	only in Autumn, reduce currents measurements, reduce ADSP	current measurements, ADSP in winter, spring and autumn
	Zooplankton production	biannual	only one period (May or autumn). And only use of WP2.	Two times every year (June and Autumn), whole Barents Sea. Use of Mocness.
	Calanus ssp	biannual	only one period (May or autumn). And only use of WP2	Two times every year (June and Autumn), whole Barents Sea. Use of Mocness/Multinet.
	Krill/Species composition	biannual	only one period (summer or autunm). And only use of WP2 and Harstad trawl	Two times every year (Winter, Summer and Autumn), whole Barents Sea. Use of Mocness/Multinet and Harstad trawl.
	Amphipods/Species composition	biannual	only one period (May or autumn). And only use of WP2 and Harstad trawl	Every year (Autumn), whole Barents Sea. Use of Mocness/Multinet
	Gelatinous (Cyanea capillata, Aurelia aurita, Ctenophores, Mentensii ovum)	biannual	only one period (May or autumn). And only use of WP2 and Harstad trawl	Every year (Autumn), whole Barents Sea. Use of Mocness/Multinet and Harstad trawl.
	Introduced species	biannual	only autumn (bottom and pelagic trawls), only length	Sampling during August-October, weight and lenght measurements
	Sensitive species	biannual	Bicatch in bottom trawl biennially on chosen stations, Identify some to species, other to groups, Direct sampling on chosen stations.	Sampling during August-October, weight, lenght, (age) measurements
	Fish biodiversity/ distribution of bio-geographic groups/ biomass	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification

	Ammodytes marinus/ Sandeel	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification
	Trisopterus esmarki/ Norway pout	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification
	Leptagonus decagonus/ Atlantic poacher	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification
	Lycodes spp.	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification
	Navaga	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ some age samples. Species identification
	Other species: Arctic skate and Greenland shark	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	One time every year. Measurements of length and weight. Species identification to family level	Two times every year. Winter and Autumn: length/weight/ sex. Species identification
	Marine mammals/ distribution/numbers	Biannial coverage, partial coverage of the open water areas	Annual coverage, complete coverage of the open water areas - including ice edge	Early and late summer coverage, due to changing distributions across seasons and seasonally changing trophic interactions
	Trophic interactions	Biennial, No length/weight/age samples, no stomach analysis, Only Norwegian or Russian sone	each second year stomach analyses of capelin and polar cod, and every year (winter) stomach sampling of cod	Every year stomach analyses from cod (winter, autumn), capelin (autumn) and polar cod (autumn)

Areas	Standard survey area	Reduced the nesseserly time for covering area	BESS-winter- 1(NO)+1 (RU) vessels , BESS-autumn: 90 days at sea, 3 (NO) vessels and 2 (RU) vessels	BESS-winter- 1(NO)+1 (RU) vessels , BESS-autumn: 80 days at sea, 2 (NO) vessels. Additional time for increased area
Co-operation	Survey planning, carrying out and reporting	Onesited research	Cooperation advice, Coordinated sampling methods	Joint planning and execution, Coordinated sampling and calculation methods, Cooperation research and advice.
Research	Process studies and methodological developments	No survey time dedicated to process studies or methodological developments	1-5 days of survey dedicated to process studies or methodological developments per year	Extra days of survey dedicated to process studies or methodological developments. Minimum average of 10 days per year.
Other concerns	Time series	biannual, redused coverage	Every year, core area, biological sampling sufficiently frequent to make an abundance estimation	Every year. Biological sampling sufficiently frequent over whole distribution area to make an abundance estimation with an acceptable level of uncertainty.
	Seasonal coverage	No dedicated effort to sample with adequate seasonal coverage	No regular seasonal coverage, but dedicated effort in one or several areas every few (5?) years.	All areas covered for each quarter at least bi-annually
	Rented vs. IMR vessels	50% of survey time on IMR vessels	80% of survey time on IMR vessels	100% of survey time on IMR vessels

Appendix 5. Fish species and the optimal time for the monitoring in the Barents Sea.

Family	Optimal timing sub-optimal timing limited information impossible to cover unknown	Coverage period: January		February		March		April		May		June		July		August		September		October		November		December		Optimal coverage area
		1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	1. part	2. part	
Agonidae	Agonus cataphractus/ hooknose																									SE
Agonidae	Aspidophoroides olrikii/ Arctic alligatorfish																									E, SE
Ammo-dytidae	Ammodytes sp./ Sandeels																									S, W, E, SW, SE
	Ammodytes tobianus/ Small sandeel																									
Argenti-nidae	Argentina silus/ Greater argentine																									SW, W, slope
Chimae-ridae	Chimaera monstrosa/ Rabbitfish																									SW
Clupeidae	Clupea harengus/ Kanin herring																									SE
Cottidae	Artediellus atlanticus/ Atlantic hookear sculpin																									whole BS
	Artediellus scaber/ Rough hamecon																									SE
	Cottidae g.sp./ Bullheads and Sculpins																									
	Gymnocanthus tricuspis/ Arctic staghorn sculpin																									NW, E, SE
	Icelus bicornis/ Twohorn sculpin																									N, E, NW, NW, SE
	Icelus spatula/ Twohorn sculpin																									Center
	Myoxocephalus aenaeus/ Grubby																									
	Myoxocephalus scorpius/																									E, SE, NW

	Shorthhorn sculpin	
	Triglops murrayi/ Moustache sculpin	S, W, N, E, SW, NW, SE
Cyclop-teridae	Eumicrotremus derjugini/ Leatherfin lumpsucker	N, E
Cyclop-teridae	Eumicrotremus spinosus/ Atlantic spiny lumpsucker	N, NW, E
Etmop-teridae	Etmopterus spinax	SW
Gadidae	Arctogadus glacialis/ Arctic cod	N, NW, NE
	Eleginus nawaga/ Atlantic navaga	SE
	Enchelyopus cimbrius/ Fourbeard rockling	S, W, SW
	Gadiculus argenteus/ Silvery pout	S, SW
	Gaidropsarus argentatus/ Arctic threebearded rockling	W, N, NW
	Merlangius merlangius/ Whiting	S, SE
	Molva molva/ Ling	W, SW
	Phycis blennoides/ greater forkbeard	S, SW
Gasteros-teidae	Gasterosteus aculeatus/ Three-spined stickleback	S, SE
Liparidae	Careproctus sp./	S, W, N, E, NW, NE
	Careproctus micropus/	
	Careproctus reinhardii/ Sea tadpole	
	Liparis fabricii/ Gelatinous snailfish	N, E, NW, NE, SE
	Liparis bathyarcticus/ Variagated snailfish	N, E, NW, NE, SE
	Liparis montague/ Montagu's sea snail	

	Liparis tunicatus/ kelp snailfish																									W, N, Center
	Liparis sp./ Sea snails																									
Lophiidae	Lophius piscatorius/ Anglerfish																									SW
Lotidae	Brosme brosme/ Cusk																									S, W, SW
Macrou-ridae	Macrourus berglax/ Rough rattail																									W, NW, SW
Mycto-phidae	Benthosema glaciale / Glacier lanternfish																									S, W, N, E, Center, NE, NW, SE
	Lampanyctus sp./																									NW
	Lampanyctus macdonaldi/ Rakery beaconlamp																									NW
	Notoscopelus sp./																									NW
Osme-ridae	Osmerus eperlanus/ European smelt																									SE
Paralepi-didae	Arctozenus risso/ White barracudina																									W, NW, N, S, Center
Petromy-zontidae	Lethenteron japonicum/																									SE
Pleuronec-tidae	Hippoglossus hippoglossus/ Atlantic halibut																									S, SW
	Limanda limanda/ Dab																									SE
	Microstomus kitt/ Lemon sole																									S, SW
	Pleuronectes platessa/ Europeian plaice																									S, SW, SE
Psychrolut idae	Cottunculus microps/ Polar sculpin																									S, W, N, SW, NW
	Cottunculus sadko/ Sadko sculpin																									
Rajidae	Amblyraja radiate/ Thorny skate																									NW, W, S, C
	Bathyraja spinicauda/ Spinetail ray																									SW, slope

	Dipturus linteus/ Sailray	SW, slope
	Rajella fyllae/ Round ray	SW, slope
Salmo-nidae	Salmo salar/ Atlantic salmon	S, SE, W, SW, Center
Scombri-dae	Scomber scombrus/ Mackerel	W, SW
Sternopty-chidae	Maurolicus muelleri/ Pearlside	SW, NW, W, center
Stichae-idae	Anisarchus medius/ Stout eelblenny	W, Nw, E, SE, Center
	Leptoclinus sp., Lumpenus sp./	
	Leptoclinus maculates/ Daubed shanny	W, N, E, NW, SE, center
	Lumpenus fabricii/ slender eelblenny	E, SE
Stichae-idae	Lumpenus lampretaeformis/Snake blenny	S, W, N, E, SE, SW, NW, Center
Syngna-thidae	Entelurus aequoreus/ snake pipefish	S, W, SW, NW
Triglidae	Eutrigla gurnardus/ Grey gurnard	S, SW
Zoarcidae	Gymnelus retrodorsalis/ Aurora unernak	N, E, NW, SE
	Gymnelus viridis/ Fish doctor	
	Lycodes esmarkii/ Esmark's eelpout	S, W, NW, N
	Lycodes eudipleurostictus/ Double line eelpout	W, N, NW, Center
	Lycodes gracilis/ Vahl's eelpout	S, W, NW, SW, Center
	Lycodes pallidus/ Pale eelpout	N, NW, NE, E, Center
	Lycodes polaris/ Canadian eelpout	E, NE, SE

	Lycodes reticulates/ Arctic eelpout																									N, NE, NW, Center
	Lycodes rossi/ Threespot eelpout																									N, NE, NW, Center
	Lycodes seminudus/ Longear eelpout																									N, NE, NW, Center
	Lycodes squamiventer/ Scalebelly eelpout																									W, NW, NE
	Lycodonus flagellicauda/																									W, NW
	Lycenchelys kolthoffi/ Checkered wolf eel																									N, NW, NE
	Lychenchelus muraena/ Moray wolf eel																									NW