Annex 02C - Stock Annex: Norwegian Spring Spawning Herring

Stock specific documentation of standard assessment procedures used by ICES.

Stock	**Norwegian Spring Spawning herring**
Working Group:	**WGWIDE**
Date:	**13 November 2013 of last revision**
Revised by	**WGWIDE**

A. General

A.1.1 Stock definition

The Norwegian spring spawning herring (*Clupea harengus*) is the largest herring stock in the world. It is widely distributed and highly migratory throughout large parts of the NE Atlantic during its lifespan. Formally, the description of the Norwegian spring spawning herring stock is not linked to specific areas and the ICES advice applies to all areas where it occurs. By far the majority of the stock occurs in Divisions IIa,b Va,b and XIVa. Juveniles of the stock have their nurseries in Division Ia. In some years, small amounts of Norwegian spring spawning herring can be found in adjacent areas mixing with other herring stocks.

It is a herring type with high number of vertebrae, large size at age, large maximum size, different scale characteristics from other herring stocks and large variation in year class strength. The herring spawns along the Norwegian west coast in February-April. Large variations in the north-south distribution of the spawning areas have been observed through the centuries. The larvae drift north and northeast and distribute as 0–group in fjords along the Norwegian coast and in the Barents Sea. The Barents Sea is by far the most important juvenile area for the large year classes, which form the basis for the large production-potential of the stock. Some year classes are in addition distributed into the Norwegian Sea basin as 0–group. Examples of this are the 1950 and 2002 year classes. Most of the young herring leave the Barents Sea as 3 years old and feed in the north-eastern Norwegian Sea for 1–2 years before recruiting to the spawning stock. Large year classes typically mature at a higher mean age due to density dependent distribution and growth. However, exceptions occur and the 2002 year class is a large year class, which has shown quick growth and a relatively early maturation. Juveniles growing up in the Norwegian Sea grow faster than those in the Barents Sea and mature one year earlier. With maturation the young herring start joining the adult feeding migration in the Norwegian Sea. The feeding migration starts just after spawning with the maximum feeding intensity and condition increase occurring from late May until early July. The feeding migration is in general length dependent, meaning that the largest and oldest fish perform longer and typically more western migrations than the younger ones. After the dispersed feeding migration the herring concentrate in one or more wintering areas in September-October. These areas are unstable and since 1950 the stock has used at least 6 different wintering areas in different periods. During the 1950s and 1960s they were situated east of Iceland and since around 1970 in Norwegian fjords. In 2001–2002 a new wintering area was established off the Norwegian coast between 69º30′N and 72ºN and in 2007\2009 no herring was observed in the fiords in winter. After wintering, the spawning migration starts around mid January.

Norwegian spring spawning herring is one the few stocks for which data have been collected over a very long period. Figure A.1.1.1 shows the dynamics of the stock in the past century indicated by assessments which go back to 1907.

A.1.2. Migration

A characteristic feature of this herring stock is a very flexible and varying migration pattern. The migration is characterised as relatively stable periods and periods characterised by large changes occurring at varying time intervals. The changes may or may not be correlated between the major distribution areas: Spawning, feeding and wintering. At present we see a period of large changes in both the wintering and feeding area. Until about 2002 the bulk of the adult herring wintered in fjords in northern Norway. The 1998 and 1999 year classes were expected to enter the fjords around 2002, but were instead observed wintering off the coast in the ocean off Vesterålen/Troms, between 69º30′N–72ºN. This continued in the years to come and in 2005 also the 2002 year class was observed wintering in the same area. During these years, the amount of older herring wintering in the fjords has decreased rapidly and during the winter 2007 and 2008 no herring was observed in the fjords. The survey covering the oceanic wintering area in November have shown a strong decrease in the biomass in the wintering stock in the area, indicating that may be a third and so for unknown wintering area could be under establishment somewhere else. Such a development is supported by the western feeding distribution in recent years, and the fact that the return migration of the smaller herring feeding in the west could be too long compared with comparable return migration distances observed in earlier periods. It is also supported by the fact that the international survey in May did not show any such negative trend in the stock.

In May the herring is migrating westward into the Norwegian Sea to start feeding and main concentrations are found in the central part of this area. In July the herring are spread out over a wide area feeding around the fringes of the Norwegian Sea, particularly in the northern and western region, while almost no herring are observed in the central region.

During the autumn in the period 2004–2008 Norwegian spring spawning herring has been caught as bycatch in smaller concentrations in catches of Icelandic summer spawning herring off the Icelandic east coast. This feature is probably linked to the western movement of the south-western summer feeding area. It is not known whether Norwegian spring spawning herring are wintering in this area.

A.2. Fishery and management

The fishery is regulated and carried out by the Coastal States. The TAC is set by the Coastal States and derived from an agreed long term management plan. The Coastal States also agree on the allocation of the TAC into national quota. The Coastal States involved are the European Union, Faroe Islands, Iceland, Norway and the Russian Federation. The fishery is carried out all year round by purse seines and pelagic trawlers. The catches are used as well for reduction purposes and human consumption. The traditional fishing pattern follows the clockwise migration pattern of the herring. Changes in the migration pattern have occurred in the past and consequently also leading to changes in the fishery, following the fish. The migration pattern, together with environmental factors, was mapped in 2008 during the ICES PGNAPES (Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys) investigations (ICES 2008/RMC:05).

Due to limitations by some countries to enter the EEZs of other countries the fisheries do not necessarily depict the distribution of herring in the Norwegian Sea and the preferred fishing pattern of the fleets given free access to any zone.

Most of the catches consist of herring only and discarding is absent or very low. In recent years increasing amounts of bycatch of mackerel are reported on the traditional fishing grounds, pointing to a change in de distribution of mackerel.

A.3. Ecosystem aspects

Norwegian spring spawning herring is a straddling stock. Juveniles and adults of this stock form an important part of the ecosystems in the Barents Sea, the Norwegian Sea, and the Norwegian coast. Herring has an important role as food resource to higher trophic levels (e.g. large fish, seabirds, and marine mammals), but also as a consumer of zooplankton in the Norwegian Sea and capelin larvae in the Barents Sea. A high stock size will therefore have positive effects on its predators, but the effects on other pelagic fish stocks feeding in the Norwegian Sea such as blue whiting and mackerel may be negative due to competition for food.

Changes in the herring migration in the first decade of the 21th century have led to an increased proportion of the population feeding in Faroese and Icelandic waters. The growth of these herring is faster than those feeding further east and north.

Not much information is available on the impact of the herring fishery on the ecosystem. The fishery is entirely pelagic. There is little quantitative information on the bycatches in the fisheries for herring but these are thought to be small. Therefore unintended effects of the fishery on the ecosystem are probably small or absent. Since herring is a major source of food for some populations of other species, overfishing of the herring stock could affect these populations. This is presently not the case since the herring stock is very abundant and is exploited at a low rate.

B. Data

B.1. Commercial catch

B.1.1. Nominal catch

The catches used in the assessment are the catches provided by the Working Group members.

B.1.2. Catch at age

From each country participating in the herring fishery exists a data delivery sheet containing at minimum information about total catch in tons by quarter of the year and ICES area. If the fleet has taken samples then catch in numbers by age, mean weight at age and mean length at age for each quarter of the year and ICES area are provided. Catch in tonnes by ICES rectangles and quarters are also reported. These sheets are combined into one file, the so called 'disfad' file. None sampled catches have then to be allocated to sampled ones. To do so positions of the catches by fleet are plotted, to see where the fleet was operating. Mean weights and mean lengths behind the sampled catches are also plotted. On the basis on these inspections allocations are done. Then the program SALLOC (ICES 1998/ACFM:18) is used to calculate the total international catch in numbers. Output from SALLOC is total catches in numbers by age as well as by quarters and areas. INTERCATCH is only used for archiving the data used in the assessment.

B.1.3. Weight at age of the catch

Annual weight at age of the catch originate from national sampling programmes of the commercial catches. They are provided by most fishing nations each year on a quarterly basis. The weight at age of the catch used in the assessment is the average of the different nations weighted over the associated catch numbers. Mean weights by age in the catch by age is also output from SALLOC.

B.1.4. Length at age of the catch

Mean length by age in the catch is calculated the same way as mean weight at age of the catch. It is not used in the assessment Mean length by age in the catch is also output from SALLOC.

B.2. Biological parameters

B.2.2. Weight at age of the stock

Up to 2008 weight of age of the stock was taken from the Norwegian survey in the wintering area (reference). The survey has stopped in 2008. From 2009 onwards weight at age of the stock is taken from commercial catches taken in the same area and period as the Norwegian survey. In 2010 sampling of data on weight at age in the stock in this period and area has increased to improve the precision of the estimates.

B.2.3. Natural mortality

B.2.3.1. History of the use of M in the assessment

The back ground of the natural mortality used in the assessment has been reviewed in the 2008 benchmark assessment of this stock. By scanning through the Working Group reports from 1990 to 2007 it was noticed that different values had been used for natural mortality at age through the years. In some years an additional mortality at age had been applied because of a disease. But taken directly from the 1997 WGNPBW-report (ICES 1997): "Values of natural mortality assumed by the Working Group previously (ICES 1996/ASSESS:14) for ages 3 and older were 0.16 for the years 1950 to 1970 and 0.13 for the years 1971 and subsequently. In the previous assessment of this stock it was assumed (on the basis of observations of many diseased and dying fish in catches) that the fish of the 1987 cohorts and older had suffered a higher natural mortality in the years 1991 to 1994. An additional disease-induced natural mortality of 0.1 was assumed. However, interim studies (Patterson, WD 1997; Tjelmeland WD 1997) directed at estimating disease-induced mortality have failed to provide compelling evidence for values above zero. Attempts to estimate natural mortality from tagging information (Hamre, WD 1997; Patterson, WD 1997a; Tjelmeland, WD 1997) were highly consistent with values in the range 0.13 to 0.16, but the Working Group did not consider that this parameter could be estimated with sufficient precision to justify a discrimination between levels of 0.13 and 0.16. Consequently it was decided to predicate the assessment model estimates on an arbitrarily-chosen M=0.15 for ages 3 and older, and no attempt was made to include additional disease-induced mortality in the maximum likelihood assessment model."

This value M=0.15 has been used for ages 3 and older since the assessment in 1997 (for all years) until the assessment made in 2005 (ICES 2005). Then a value of 0.5 was used for the plus group (16+) and was used until 2007. This increase of M was done in order to get the SSB at low values in the collapsed phase in the 1970s. It caused only a slight decrease of the SSB in the recent years (ICES 2005).

From 2008 onwards age 15 is used in the assessment as a plus group and a value of M=0.15 is used.

In the Working Group report from 1992 (ICES 1992) a comparison of acoustic estimates for year classes 1983-1985 and 1988, and the same year classes as 3 year old (VPA) gave an average annual M=0.88, so M=0.9 was used for ages 0-2.

For ages 0-2 then the following is stated in the report from 1997 (ICES 1997): "Values of natural mortality for juvenile fish (ages 0-2) used by the Working Group in 1996 were 0.9 for all years in historic VPA, but for forecasting purposes values of 1.56 for age 1 and 0.54 for age 2 were used for the 199-1995 year classes. These values were based on an unpublished Ph.D. Thesis by de Barros (1995); this work was not available for evaluation by the Working Group, and hence it was decided to retain the assumption of M=0.9 for ages 0 to 2 in all years. This value is consistent with the mean of de Barros' estimates." This value of M=0.9 is still used in the present assessments for ages 0-2.

B.2.3.1. M used in the present assessments

In the benchmark assessment, the natural mortality M=0.15 was used for ages 3 and older and M=0.9 was used for ages 0–2 in all years from 1988 onwards.

B.2.4. Maturity at age

In 2010 WKHERMAT evaluated the information on maturity for this stock. This work was planned to be carried out in the benchmark assessment in 2008 but at that time this information was not available. WKHERMAT proposed to used maturity o-gives based on back calculation of rings on the scale. This information provided a long time series which is reproducible. WGWIDE introduced this times series in the 2010 assessment.

B.2.4.1. Maturity data used in the assessments prior to 2010

The text in italics in the following paragraphs in this section is old text and no longer valid

Except for the year class 2002, the proportion mature at age used in assessment has generally been the same during the last ten years (Table B.2.4.1).

The growth rate of the 2002 year class has been higher than usually seen in large year classes of this stock. One reason for this is that a large part of the juveniles stayed in the Norwegian Sea as juveniles, favouring quicker growth than in the Barents Sea, which is the area where juveniles normally are distributed.

The proportion mature of this year class was calculated from samples collected during the surveys in the wintering area in November (before spawning) and in the Norwegian Sea in May (after spawning). The proportion of fishes in maturation stage 3 or larger (fish to spawn) in November 2005 was used as a first proxy to the proportion maturing. The proportion maturing according to these data was 0.85. The proportion in stages >5 (spent) in May was used as a proxy for the proportion having spawned. The proportion having spawned according to these data was 0.92. Based on these observations and calculations 0.9 was adopted as proportion mature of the 2002 year class at age 4. Based on this 1.0 instead of 0.9 was adopted as proportion mature of the 2002 year class at age 5. All other year classes in the later years were set at the standard 0.3 at age 4, 0.9 at age 5 and 1.0 at age 6 both in the assessment and predictions.

The Working Group has accepted the present values for the use in the assessment but considers that there is a need to validate the presently assumed values in particular for the most recent years. The proportion mature at age used in assessment is based on various surveys carried out *many years ago and is not always well documented. The Working Group acknowledged the potential problem of obtaining random samples of proportion mature at age from survey for this stock due to the different catchability of mature and immature fish of the same age groups caused by spatial segregation. An alternative method for estimating proportion mature at age was proposed to the Working Group. This method involves back-calculation of proportion mature at age from fully matured year classes and is based on work done by Engelhard et al. (2003) and Engelhard and Heino (2004). The Working Group found this approach interesting, but decided to explore it further before any decision should be taken regarding using it in assessment. The Working Group recommends that effort should be put into updating estimates on proportion mature at age from recent years with this method and compare it with data on direct measurements on proportion mature at age from the May survey during the period since 1997 when this survey was assumed to cover the entire stock. This work will be done by IMR but has not completed yet. Based on this, an evaluation will be done and may lead to revisions of the maturity 0-gives in the past.*

The surveys in the wintering area in November (reference) have stopped in 2008. From 2008 onwards only information is available from the May survey (reference). In 2009, WGWIDE has recommended to adjust (increase) the sampling for maturity in this survey in the May survey to ensure sufficient coverage (spatial and by age) of the data.

The old time series is not longer used and is presented in the stock annex.

B.2.4.2. Maturity data used in the assessments from 2010 onwards (inserted in 2011)

In 2010 a Workshop (WKHERMAT)[1] was held to evaluate existing maturity at age data. The Workshop was held because data on maturation were not available and considered in the benchmark assessment in 2008. The work of the Workshop therefore concludes the benchmark process. Three sources of maturity information were considered. The three different data sources were: a) maturity ogive used in assessment, b) survey data on maturity staging collected during surveys 4 and 5 and c) back-calculated maturity ogive using Gulland's method. In addition, data on maturity cycle in Norwegian spring spawning herring were presented and guidelines for sampling of maturity data were discussed in accordance with PGCCDBS.

The maturity matrix used in the ICES assessment goes back to 1907. Documentation on the source of information and the justification of changes is almost absent and the lack of documentation is a general problem in this data set. The data cannot be reproduced because the sources are unknown and most changes which have been made in the past cannot be explained.

The May surveys may potentially provide data to construct updated maturity ogives for the most recent years. The surveys indicate that most (but not all) herring in the Norwegian Sea are mature and most (but not all) herring in the Barents Sea are immature. However, the time series is short and there are some problems. For the age groups which occur both in the Norwegian Sea and Barents Sea, quantitative information on annual abundance is required for a the calculated weighted average maturity representative for the stock in both areas combined. The available information on the distribution of these age groups in not very reliable because there appear to be differences

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[1] Report of the Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT). 1-3 March 2010 Bergen, Norway. ICES CM 2010/ACOM:51 REF. PGCCDBS

in the catchability in the survey between the Norwegian Sea and the Barents Sea. This needs to be addressed further before data from the survey can be used for maturity ogive estimations.

The back calculation data set indicates that maturation of ages 3, 4 and 5 has varied considerable over time and that maturation of large year classes is slower than for others. This applies to a lesser extend to the 2002 year class. However, the estimates for this year class are suggesting that at least a correction needs to be considered in the maturation assumed for this year class in previous assessments by ICES. WKHERMAT considered the data set derived by back calculation as a suitable potential candidate for use in the assessment because it is conceived in a consistent way over the whole time period and can meet standards required in a quality controlled process. However, the back calculation estimates cannot be used for recent years. Since the surveys do not provide suitable data at the moment, assumptions have to be made for recent year classes.

WGWIDE considered the results of WKHERMAT in 2010 and adopted the maturity o-gives derived from back calculation of scales for the historical time period (years 1950-2007) in the assessment. WGWIDE recommends that this data set remains updated in future years. For the years after 2007 for which no data are available from this method (including the years considered in the forecast) the following default maturity o-gives will be assumed. For 'normal' classes (average, median and weak year classes), an average maturity at age will be assumed from the periods 1983-2007 from the back calculation data set excluding the strong year classes 1983, 1991, 1992, 1998, 1999, 2002. For year classes which are considered strong, preliminary estimates will be assumed to be the average of the recent strong year classes 1983, 1991, 1992, 1998, 1999, 2002 in the data set.

The default maturity o-gives used for 'normal' and strong year classes are given in the text table below.

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
normal yc	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
strong yc	0	0	0	0	0.1	0.6	0.9	1	1	1	1	1	1	1	1	1

A comparison of the old and new time series in given in the WKHERMAT report. The maturity ogives used in previous assessments are given in Table B.2.4.1. The maturity ogives used in the present assessment are presented in the WGWIDE report.

Except for those periods where strong year classes enter the stock, the revision of the maturity at age matrix affects has little effect on the estimates of SSB in the historical time series. Because strong year classes show slower maturation, the SSB estimates in periods where strong year classes recruit in the stock have been revised downwards compared to previous ICES assessments.

B.2.4.3 Terminal F calculation (added 2013)

The preliminary assessment in 2013 following the 2008 benchmark revealed the same strong retrospective patterns as have been observed since assessment year 2010. However, adding the latest catch statistics and survey information lead to unexpectedly large changes in the perception of the stock, particularly in the earlier period of the assessment time series (see WD Skagen 2013 and WGWIDE 2013 report) that were considered to be out of proportion. As a result of the data exploration WGWIDE 2013 implemented an updated algorithm for calculating the terminal F-values for last age classes where no data supporting the estimate of terminal stock numbers was available.

Because some of the year classes are very small, there are no data to estimate the terminal stock numbers in the VPA (before 1982, 1984 – 1988, 1995 and 2000 – 2001). In the 2008 benchmark the derivation of the terminal fishing mortalities for those of these year classes that had reached oldest true age, was defined as derived from the terminal F the year before and fishing mortalities at younger ages, with the standard procedure in TASACS. However, because of the sensitivity of this method to noise particularly in the estimates of older age groups, Skagen (WD to WGWIDE 2013) suggested a new algorithm for this derivation. The new algorithm for deriving the terminal stock numbers for these year classes assumes a fixed ratio between F at oldest age and average F in the year, which is equivalent to assuming a fixed selection at oldest age. Similar method is used in the assessment model ICA, and in the separable option in TASACS. The ratio is taken from the selection parameters, as the selection at oldest age relative to the mean over the ages 5 - 13. There is no standard way to estimate that ratio. However, a sensitivity analysis showed that the the exact ratio used has only a minor influence on the estimated numbers in the earlier time period and none on the latest part of the times series. Values between 1.1 and 1.7 give comparable results. The ratio between the terminal F and the average F over ages 5-13 calculated for all the years where terminal F is estimated is 1.3 (excluding all F = 0), and this was applied in the 2013 assessment. B.3. Surveys

A number of surveys on this stock have been carried out in the Norwegian Sea and Barents Sea to estimate the size of the stock, its age composition or the recruitment to the stock. Some of the surveys have stopped but data are still used in the assessment The surveys and its potential use are described in the sections below.

B.3.1. Survey 1. Norwegian acoustic survey on spawning grounds in February/March

<u>Background and status</u>

The survey has been carried out since 1988 but not in every year. The survey will not be carried out after 2008.

<u>Use of this survey in stock assessment</u>

The age groups 5–15+ have been used in the assessment for the years 1994 to 2005. After this year the survey has not been used in the assessment. The reason for this being that the survey was carried out very earlier and before the herring had reached the spawning grounds, with the possibilities of herring emerging the spawning grounds also through other routes than those covered in the survey.

<u>Results</u>

Results can be found in Table B.3.1.1 and Figure B.3.1.1.

B.3.2. Survey 2. Norwegian acoustic survey in November/December

<u>Background and status</u>

The survey has been carried out by Norway since 1992 in the Norwegian fjords where the adult herring winter. Since 2003 also the oceanic areas north of Lofoten/Vesterålen has been included in the survey to take account of changes in the wintering area. The fjordic coverage was ceased during the winter 2007/2008 because the herring had totally left the fjords.

Results

In 2007 the RV Johan Hjort carried out an acoustic survey in the oceanic wintering area in northern Norway (Figure B.3.2.1). The results of this survey are shown in Table B.3.2.1. This survey covers the known wintering area of the mature part of the stock. The survey gave a very low biomass estimate due to unknown reasons. One possible explanation is that a new wintering area is building up somewhere else. This has so far not been confirmed and remains an open question.

Use of this survey in stock assessment

Given the large changes in the wintering pattern of herring and the possibility of a third and undescribed wintering area, it was decided not to use this survey for the period following the new wintering pattern of the herring in the assessment. The survey will not be continued by Norway and will not be carried from 2008 onwards.

B.3.3. Survey 3. Norwegian acoustic survey in January

Background and status

This survey was carried out by Norway in the fjords in the period 1991–1999.

Results

The results of the survey in the wintering area in January can be found in Table B.3.3.1.

Use of this survey in stock assessment

Although the survey series has ended, the data are still used in the assessment. The age groups 5–15+ from 1991 to 1999 are currently used.

B.3.4. Survey 4 and 5. International ecosystem survey in the Nordic Seas

Background and status

The international ecosystem survey in the Nordic Seas is aimed at observing the pelagic ecosystem, focusing herring, blue whiting, zooplankton and hydrography. The survey, carried out since 1995, is coordinated by the ICES PGNAPES (ICES CM 2009/RMC:06) and is a cooperative effort by Faroes, Iceland, Norway, Russia, and the EU (Denmark, Germany, Ireland, The Netherlands, Sweden and UK). This trawl-acoustic survey supplies the most important time series for the assessment of NSSH and also a time series for young blue whiting in the juvenile areas.

Results

The age-disaggregated time-series of abundance for the Barents Sea and Norwegian Sea are presented in Table B.3.4.1. and Table B.3.4.2.

Survey covering the entire stock during its migration on the feeding grounds. An example of the coverage of the survey (2009) is given in Figure B.3.4.1.

Use of this survey in stock assessment

From the area west of 20°E the full time series of age groups 4 and older in survey 5 are used for the assessment. Survey 4 in the area east of 20°E covering the Barents Sea has been used in the final assessment from 2005 onwards. The survey supplies the recruitment for age groups 1 and 2 in the assessment. No data exist for 2003 and 2004 in this survey. The data for 2008 are not used. The data for survey 4 are also used for estimating recruitment in RCT3.

B.3.5. Survey 6 and 7. Joined Russian–Norwegian ecosystem autumn survey in the Barents Sea

Background and status

The survey consists of a trawl survey catching 0–group herring amongst other species and an acoustic survey estimating one and two year old herring. In 2001, the Working Group decided to include data on immature herring obtained during the Russian-Norwegian survey in August-October in estimating the younger year classes in the Barents Sea.

Results

The results from these surveys on 0–group herring are given in Table B.3.5.1. The results for the 1 to 3 age groups are given in Table B.3.5.2. The youngest age groups (0+ to 3+) of the Norwegian spring spawning herring stock are found in the Barents Sea at irregular intervals. It is difficult to access the stock size during autumn, due to various reasons. The age groups 1 to 3 are found mixed with 0–group herring and are difficult to catch in the sampling trawl used in this survey. The stock size estimates of herring are therefore considered less reliable than those for capelin and polar cod. An example of the distribution of young herring is shown in Figure B.3.5.1. An example of the distribution of 0–group herring is presented in Figure B.3.5.2.

Use of this survey in stock assessment

The indices of age groups 1 and 2 of survey 6 are used in the assessment with the exception of 2002.. The index of survey 7 is used for the estimation of recruitment by RCT3.

B.3.6 Survey 8 Norwegian herring larvae survey on the Norwegian shelf

Background and status

A Norwegian herring larvae survey has been carried out on the Norwegian shelf since 1981 during March-April. The objectives of the survey are to map the distribution of herring larvae and other fish larvae on the spawning grounds on the Norwegian shelf and to collect data on hydrography, nutrients, chlorophyll and zooplankton. The larval indices are used as indicator of the size of the spawning stock. Two indices are available from this survey.

Results

Two larvae indices are available from this survey and presented in Table B.3.6.1. Index 1 represents the total number of herring larvae found during the survey. Index 2 represents the back-calculated number of newly hatched larvae assuming 10% daily mortality. Examples of the distribution of the herring larvae are given in Figure B.3.6.1.

Use of this survey in stock assessment

The "Index 1" is used in the assessment as representative for the size of the spawning stock except for the years 2003 and 2009 (Table B.3.6.1).

B.3.7 Survey 9 International ecosystem summer survey in Nordic Sea

Background and status

This ecosystem survey initiated in 2004 by Norway and have since then been gradually expanded in geographical coverage and scientific complexity (e.g. Nøttestad and Jacobsen 2009). In 2009, and 2010, the survey coverage was expanded further with participations of vessels from Iceland and the Faroese in addition to two vessels from

Norway. The main objective of the survey is to study abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and other pelagic species in relation to oceanographic conditions, prey communities and marine mammals. Two different types and independent abundance estimates for herring can de derived from the survey, an acoustic estimate, and swept area estimate from pre-defined surface trawl stations.

Results

The survey was extended very much in 2009, so the acoustic estimates for herring since then (Table B.3.7.1) are not comparable to the previous estimates. An example of the coverage of the survey (2010) is given in Figure B.3.7.1.

Use of this survey in stock assessment

The time series where the herring stock has been covered adequately goes only back to 2009. Thus, the survey has not been used directly in the assessment of NSSH.

B.4. Commercial CPUE

No commercial CPUE data are used in the assessment.

B.5. Other relevant data

With the exception of 1999, 2001 and 2005, tagging has been carried out annually between 1975 and 2007. In 2007 Norway has decided to discontinue the tagging program in 2008 and in future years.

The use of the tagging data in the assessment was discontinued since 2006 due to a low number of recaptures. This comes as a result of too low tag density in the stock given the high stock size and amount of fish screened for tags.

C. Historical Stock Development

Model used: VPA

Software used: TASACS, version

Model Options chosen:

Analyses are restricted to the years 1988-present

Age range for the analyses is 0-15+

Natural mortality is assumed at 0.9 for ages 0, 1 and 2 and 0.15 for all older ages.

Assumed fraction of fishing mortality and natural mortality for each of the age-structured surveys

FLEET 1	FLEET 2	FLEET 3	FLEET 4	FLEET 5	FLEET 6	FLEET 7
0.17	0.91	0.17	0.41	0.41	0.70	0.70

Catchability for the age structured surveys independent of age for ages >4

Exploration of the survey data is carried out in order to investigate whether the survey contributes information to the assessment or whether there is no or little in-formation in the survey data. In the case where the survey contributes mostly noise to the assessment it is not included in further exploration and in the final assessment. In addition, when conflicting information appears between different surveys, it is attempted, as far as possible, to use expert knowledge about the performance and known problems of the different surveys, to resolve conflicts by excluding the data that were considered the least reliable.

Rather than excluding information from the survey on a subjective basis, criteria are set for exclusion. These are set based on the general observations and the analysis of comparisons of the consistency within and between the surveys. The following criteria are used for exclusion of data:

1) Data outside the range of years and age windows selected by previous WG have also been excluded in the present assessment. Such as incomplete survey coverage of the stock of survey not completed due to other reasons.
2) Survey data of poor year classes with mostly noise are excluded. This is for instance the case for year class 1995 in all surveys.
3) Reject ages where the analysis of consistency between and within surveys indicate severe problems. For instance for survey 1, the conclusion from the correlation analyses is not to use information at ages older than age 11.
4) If there is a conflict between data from different surveys, discard the data where known problems with the survey indicates that these are the least reliable. This applied in particular to conflicts between survey 2 and survey 5, where survey 2 indicated a rapid decline in the stock and survey 5 a more gentle decline. Since representative sampling of old fish in survey 2 is a known problem, caused by vertical segregation in the wintering areas in the Lofoten fjord, the survey 2 data are ignored and the survey 5 data used. at ages above 10 years.
5) If there are internal inconsistencies in the old ages in a survey (mismatch between abundance at young and old age), the old ages are ignored.
6) No zero values are used.

All observations still included were given equal weight, except for the catches at the youngest ages, where the following weightings, relative to the standard weighting of 1.0 are used:

Age 0	0.001
Age 1	0.001
Age 2	0.01
Age 3	0.1

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1988-last data year	0-15+	Yes
Canum	Catch at age in numbers	1988-last data year	0-15+	Yes
Weca	Weight at age in the commercial catch	1988-last data year	0-15+	Yes
West	Weight at age of the spawning stock at spawning time.	1988-last data year	0-15+	Yes
Mprop	Proportion of natural mortality before spawning	1988-last data year	0-15+	Yes
Fprop	Proportion of fishing mortality before spawning	1988-last data year	0-15+	Yes
Matprop	Proportion mature at age	1988-last data year	0-15+	Fixed in later years
Natmor	Natural mortality	1988-last data year	0-15+	Yes

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Norwegian acoustic survey on spawning grounds in February/Match	1995-2005	5-15+
Tuning fleet 2	Norwegian acoustic survey in Nov/Dec	1992-2001	4-14+
Tuning fleet 3	Norwegian acoustic survey in January	1991-1999	5-15+
Tuning fleet 4	International Ecosystem survey in the Nordic Seas and	1991-last data year	1-2
Tuning fleet 5	International Ecosystem survey in the Nordic Seas	1991-last data year	4-15+
Tuning fleet 6	Joined Russian-Norwegian ecosystem autumn survey in the Barents Sea	2000-last data year	1-2
Tuning fleet 7	Joined Russian-Norwegian ecosystem autumn survey in the Barents Sea	2000-last data year	0

Tuning fleet 8	Norwegian herring larvae survey	1981-last data year

The stock summary from the 2009 assessment is included in table 9.4.5.3. The TASACS assessment covers the period 1988 to the present. The data prior to 1988 originate from the Sea Star assessment carried out in 2007?D. Short-Term Projection

Model used: Deterministic short-term projection, with management option table presenting average F-values for age 5-14 weighted over population numbers at the start of the year.

Software used: Excel spread sheet. No approved and formal tested software exists. A spreadsheet was developed because available software programmes cannot provide management option tables with annual F-factors which take account for weighted F.

Initial stock size: Input to the short-term projection are the stock number at age 4-15+ (survivors) at the 1st of January taken from the final assessment. For instance, if the last data year is 2008, the assessment provides the surviving stock numbers at the 1st of January 2009. Stock numbers at age 0-3 are estimated separately from independent data sources (for instance using RCT3).

Maturity: As a default a standard fixed maturity o-give is applied. In the case biological information is available indicating a change in proportions maturation at age, the values may be adjusted

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1

F and M before spawning: The SSB is calculated at the 1st of January. Consequently the proportion of F and M before spawning is 0.

Weight at age in the stock: for the intermediate year are the observed weights obtained from the winter survey (reference). For the other years the average of the last 3 years are used. Since 2008 the winter survey has stopped and weight at age data from commercial sampling in the same period and are used

Weight at age in the catch: is the average of the observed catch weights over the last three years.

Exploitation pattern: is the average over the last 3 years. In 2010 and 2011 the average over the last 5 years was used.

Natural mortality: fixed values, the same as used in the assessment

Intermediate year assumptions: catch constraint

Stock recruitment model used: not applicable

Procedures used for splitting projected catches: not applicable

E. Medium-Term Projections not defined

Model used:

Software used:

Initial stock size:

Natural mortality:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Intermediate year assumptions:

Stock recruitment model used:

Uncertainty models used:

1. Initial stock size:
2. Natural mortality:
3. Maturity:
4. F and M before spawning:
5. Weight at age in the stock:
6. Weight at age in the catch:
7. Exploitation pattern:
8. Intermediate year assumptions:
9. Stock recruitment model used:

F. Long-Term Projections not defined

Model used:

Software used:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Procedures used for splitting projected catches:

G. Biological Reference Points

G.1. Precautionary and limit reference points:

The reference points for herring were considered by the Workshop on Limit and Target Reference Points (WKREF) held in Gdynia in 2007. Although it was the intention to review and update the biological basis of limit reference point taking into account the possible effects of species interactions and regime shifts, this has not been done because of lack of data. Instead, the breakpoint of a segmented regression applied to the stock recruitment plot was investigated. This breakpoint gives an indication at which SSB recruitment starts to decline and is a candidate for Blim. The breakpoint in the stock recruit data varied between 2 to 4 million tonnes and seemed to be very sensitive to small changes in the estimates of the poor year classes (points near the origin of the S/R plot) in assessments carried out in different years. WKREF could not explain the sensitivity and considered this behaviour of the model highly undesirable. WKREF decided to ask the Methods Working Group to investigate this observation further. Given this, the use of segmented regression technique to establish a limit biomass reference point for Norwegian spring spawning herring was not considered appropriate until the observed methodological issue has been resolved.

The presently used values originate from an analysis carried out in 1998.

	ICES CONSIDERS THAT:	ICES PROPOSED THAT:
Precautionary Approach reference points	Blim is 2.5 million t	Bpa be set at 5.0 million t
	Flim is not considered relevant for this stock	Fpa be set at F = 0.15
Technical basis:		
Blim: MBAL		Bpa=Blim*exp(0.4*1.645) (ICES Study Group 1998)
Flim: not relevant for this stock		Fpa: based on medium term simulations (ICES Study Group 1998)

The new assessment did not give different perceptions of the dynamics and levels of SSB and Fishing Mortality compared to the assessment which was the basis for establishing the reference points. Therefore there was no need to reconsider the reference points because of the new assessment method.

MSY reference points (included in 2010)

<u>HCS Simulation model analysis</u>

HCS is a stochastic simulation model for studying different management scenarios. The parameterization of HCS for NSSH is described in a working document sent for WGWIDE in 2010 (WD, Skagen; the values for weights, natural mortality and initial N-values can be found in ICES 2009, WGWIDE Table 7.10.1.3, input to short term prediction; see also Skagen 2010, WD WKFRAME). Two stock-recruitment relationships, Beverton-Holt and hockey stick, are explored:

Beverton-Holt: $R = a*SSB/(SSB+b)$

Hockey stick: $S>b: R = a$

$S<b: R = a*SSB/b$

The stock-recruitment parameters are shown in Table 7.8.2. params, and a plot of these together with the data is shown in Figure 7.8.2.srstoch. A plot of the data together with model output for Beverton-Holt function is show in Figure 7.8.2 srmodeldata, and the cumulative distribution of recruitment in data and model output is shown in Figure 7.8.2.cumdist. The long term sustained yields with Beverton-Holt recruitment function are shown in Figure 7.8.2.catch. A similar figure for hockey stick recruitment function can be found in Skagen 2010 (WD, Skagen).

In WKHERMAT in 2010 a new maturity ogive matrix for NSSH based on a back calculation methods was estimated (ICES 2010, WKHERMAT). This is used in the assessment in 2010. There appears to be a difference in the maturation ogive between strong and weak year classes such that strong year classes tend to mature at later age compared to weak year classes (Engelhart & Heino 2004, ICES 2010, WKFRAME). However, the model used here currently allows only static maturity ogive, and in order to take into account the effect of variation in maturation of strong and weak year classes for MSY and F_{MSY} we have run the analysis using the standard maturity ogive used in assessment the latest years, an ogive estimated for weak year classes and an ogive estimated for strong year classes (Table 7.8.2.modelparams). Furthermore, in year 2009 the selection pattern is different to the historical period, appearing more dome-shaped than the historical sigmoidal selection pattern (Table 7.8.2.modelparams). We have not been able to identify any reason why the selection pattern would have changed, as there have been no changes in gear or fishery in general. Nevertheless, we also studied the effect of possible change in selection pattern by using alternatively the historical (old) or the selection curve from 2009 (Table 7.8.2.modelparams).

The results of the simulation analysis suggest that the MSY, for all the scenarios and with both stock-recruitment functions, is within the same range: between 1 and 1.2 million tonnes (Figure 7.8.2.msyBH, 7.8.2.msyHS, and Table 7.8.2.results). Even though the different scenarios result in MSY within the same range, the F_{MSY} has more variation (Figure 7.8.2.fmsy and Table 7.8.2.results). When Beverton-Holt recruitment function is used, the risk of stock going below B_{lim} (2.5 million t.) and $B_{trigger}$ (4 million t.) at F_{MSY} are both very low, whereas with the Hockey stick recruitment function the risk of the stock falling below $B_{trigger}$ at F_{MSY} is relatively high (Table 7.8.2.results). Hockey stick recruitment function appears not to be very useful in modelling population dynamics, as the spawning stock size where MSY is reached is the same point where stock reproductive capacity starts decreasing (see also the discussion in the equilibrium analysis below). When Beverton-Holt recruitment function is used, unweighted F_{MSY} using the historical fishery selection pattern is 0.16 (for all maturity ogive scenarios), and adopting the 2009 selection pattern suggests of F_{MSY} 0.12 (for all maturity ogive scenarios). In NSSH management weighted F values are used, and the weighted values tend to be somewhat lower than unweighted values (Figure 7.8.2.fvalues). As we have no reason to believe that the selection pattern has really changed, we consider unweighted F_{MSY} to be 0.16. This unweighted F value is in close agreement with the reference values originating from an analysis carried out in 1998 (ICES 2008/ACOM 13), where a weighted F_{pa} is defined as 0.150.

Equilibrium and YPR analyses

Deterministic and stochastic equilibrium analyses were carried out using the 'plotMSY' software (ICES 2010, WKFRAME) to determine candidate F_{MSY} values for the Norwegian spring spawning herring stock. Stock-recruitment pairs from the period 1988-2009, as outputted from the most recent assessment of the stock, were used together with 5-year averages of selectivity, weight and maturity at age (back-calculated ogive). Two stock recruit relationships were examined, Beverton and Holt and the ('smooth hockey stick' (segmented regression), and yield-per-recruit (YPR) analyses were also done. For the stochastic analyses, uncertainty (CVs) in the biological and fishery parameters at age were used to create alternative fits to two stock-recruit relationships (*N*=1000).

While the Beverton and Holt fit is reasonable under using the old maturity ogive to estimate SSB (results not shown), the majority of stochastic stock-recruit model fits fell out of the range of the deterministic fit to the data, and thus it can be concluded that the stock-recruit form is unclear and not suitable for the data and the level of uncertainty associated with the parameters. Using the new back-calculated maturity ogive, as has been decided by the working group for the assessment of this stock, results in an very poor Beverton and Holt fit (Figure 7.8.2.XXXsr), with an extremely steep slope at the origin and an asymptote at the geometric mean recruitment level. Given the lack of any clear patterns in the stock-recruit data, a hockey stick model fit, while uncertain around the origin, probably provides the most cautious fit to the data. For the hockey stick, the slope at the origin is the descending limb of the stock-recruit curve, which for this stock is relatively shallow, hence F_{crash} is low. The value for B_{msy} is at the breakpoint in the hockey stick, hence F_{msy} is estimated to be the same as F_{crash} (Table 7.8.2.XXXmsy). The uncertainty with regards to the slope at the origin makes this stock-recruitment function unsuitable as a basis for advice on F_{msy}. In such cases the slope is more useful as an indication of F_{pa} or F_{lim}.

Given the poor fits to stock recruitment functions, a yield-per-recruit analysis was conducted (Figure 7.8.2.XXXypr). The stochastic analysis shows a high degree of uncertainty and a very poorly defined F_{max}. That both the hockey stick and per-recruit analysis suggests a high degree of uncertainty with regards to F_{max} could be down to the assumptions made about the uncertainties input into the analyses, though these assumptions are believed to be realistic given the information on the stock. This would preclude the use of F_{max} as an F_{msy} proxy, although $F_{0.1}$ may remain a viable, safer alternative. The YPR curve shows that F values in the range 0.125-0.15 are likely to result in high long term yields.

<u>Conclusions</u>

In the equilibrium analysis, the structure of the stock and recruitment pairs as estimated from the most recent assessment does not lead to any clear definition of an optimum yield equilibrium fishing mortality level. Given this uncertainty it is more appropriate to select an F_{msy} proxy tested by a stochastic simulation model that takes into account the long term trends in the stock biomass. The simulation model results presented in this report and in the stock annex provide a more appropriate method for the determining a viable long term target, and the values from this analysis could be put forward as potential F_{msy} targets. However, it should be noted that it is clear that the estimation of MSY reference points is very sensitive to the choice of stock-recruitment function and the approach chosen to estimate the reference points. This is in accordance with previous analyses by Skagen (WD 2010) and by WKFRAME (ICES 2010, WKFRAME).

The stochastic model uses unweighted F values, which have historically been found to be slightly lower than the unweighted values (Figure 7.8.2.fvalues). Therefore, a weighted F_{msy} of 0.15 corresponding to the unweighted 0.16 F_{msy} proxy from the simulation analyses is proposed for this stock. This is in agreement with the current simulation-tested management plan F_{pa} level and should ensure high long term yield with a low risk to the stock.

Table 7.8.2.params. Norwegian spring spawning herring. Stock recruitment parameters used in the simulation model and their fit to the data (Skagen 2010).

	a-parameter	b-parameter	SSQ
Beverton-Holt	180805	6986	81.85
Hockey stick	88803	3957	81.47

Table 7.8.2.modelparams. Norwegian spring spawning herring. Age-specific maturation probabilities, exploitation patterns and weight at age in stock and in catches used in the different stochastic simulation scenarios.

	Maturity ogive			Exploitation pattern		Weight at age	
Age	historic	weak year class	Strong year class	Old	2009	stock	catch
0	0	0	0	0.00	0.00	0.001	0
1	0	0	0	0.05	0.00	0.01	0.052
2	0	0	0	0.04	0.87	0.033	0.115
3	0	0	0	0.05	0.26	0.077	0.159
4	0.3	0.4	0.1	0.18	0.29	0.141	0.225
5	0.9	0.8	0.6	0.41	0.47	0.215	0.264
6	1	1	0.9	0.67	0.84	0.27	0.301
7	1	1	1	1.03	0.93	0.306	0.32
8	1	1	1	1.10	1.01	0.336	0.338
9	1	1	1	0.81	1.65	0.346	0.359
10	1	1	1	1.03	1.10	0.364	0.366
11	1	1	1	0.77	0.73	0.369	0.375
12	1	1	1	1.42	1.14	0.411	0.391
13	1	1	1	1.36	0.59	0.353	0.397
14	1	1	1	1.39	0.56	0.389	0.396
15	1	1	1	1.39	0.56	0.393	0.406

Table 7.8.2.results. Norwegian spring spawning herring. MSY and FMSY values provided by HCS model for different scenario combinations. Risk B_{lim} refers to the probability that SSB < B_{lim} in the last year (2.5 million tonnes), and Risk $B_{trigger}$ refers to the probability that SSB < $B_{trigger}$ ($B_{trigger}$ = 5 million tonnes, risk calculated as risk B_{lim}).

		Beverton–Holt				Hockey stick			
Ogive	selection pattern	FMSY	MSY	Risk Blim	Risk Btrigger	FMSY	MSY	Risk Blim	Risk Btrigger
Historical	old	0.16	1120.1	0	0.026	0.32	1180.1	0.067	0.354
	2009	0.12	1071.5	0.006	0.064	0.2	1135.7	0.088	0.431
Weak year class	old	0.16	1132.8	0	0.022	0.32	1193.4	0.058	0.321
	2009	0.12	1083.4	0.006	0.051	0.2	1149.4	0.075	0.401
Strong year class	old	0.16	1093.3	0.002	0.045	0.26	1157.9	0.04	0.232
	2009	0.12	1046.4	0.007	0.086	0.16	1117.9	0.017	0.203

Table 7.8.2.msy. Deterministic and stochastic estimates of *F* and biomass reference points form two stock recruit relationships and yield-per-recruit analysis for the Norwegian spring spawning herring stock (*=poorly defined).

Beverton-Holt

	Fcrash	Fmsy	Bmsy	MSY
Deterministic	*	*	0.25	1.06
50%ile	0.52	0.15	3.11	0.61
CV	1.09	0.60	0.72	0.61

Hockey Stick

	Fcrash	Fmsy	Bmsy	MSY
Deterministic	0.18	0.18	4.25	0.70
50%ile	0.20	0.20	3.88	0.90
CV	0.71	0.69	0.39	0.49

Per recruit

	F01	Fmax
Deterministic	0.23	*
50%ile	0.19	0.77
CV	0.39	0.58

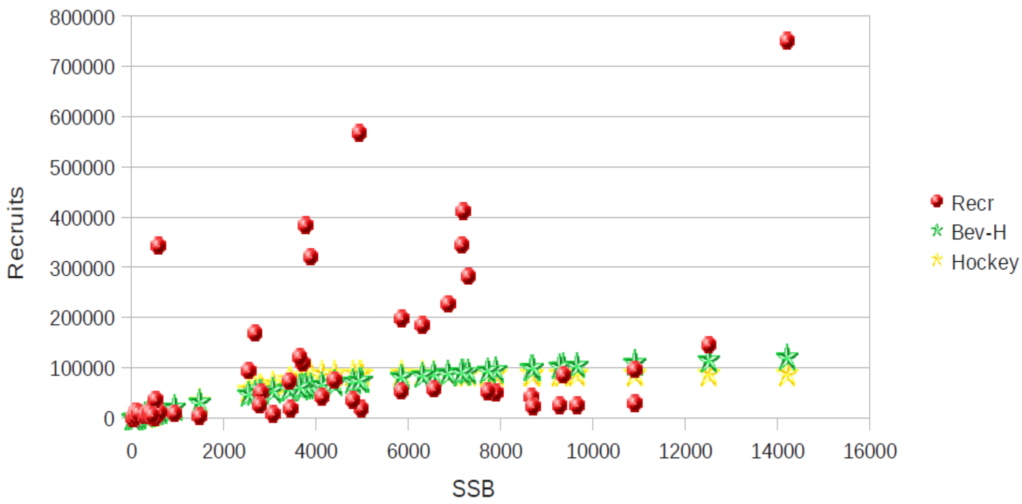

Figure 7.8.2. srstoch. Stock recruitment relationship used in the simulation model. Red dots show the recruitment from data, green stars the fitted Beverton-Holt function and yellow stars the fitted hockey stick function. Figure show also in Skagen 2010 (WD, Skagen).

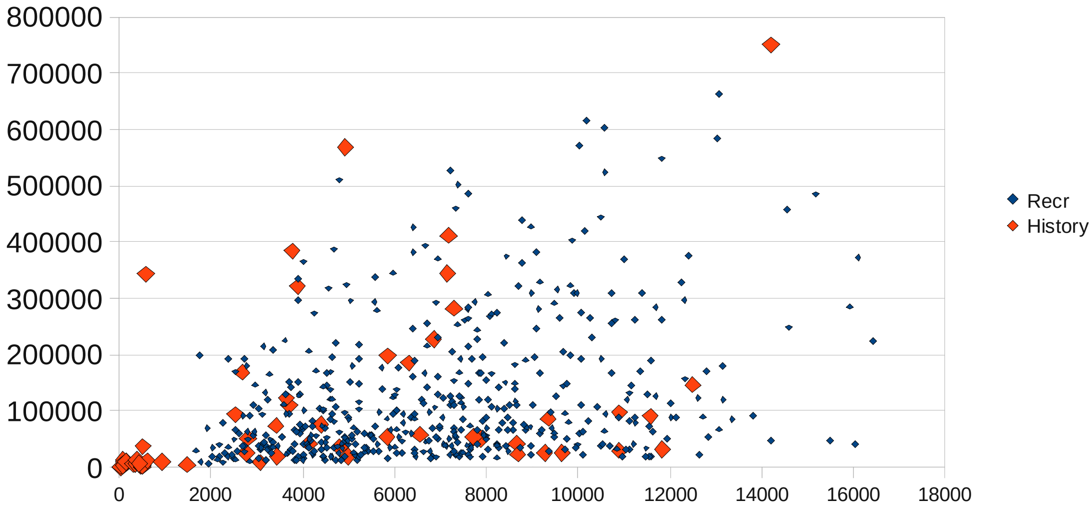

Figure 7.8.2.srmodeldata. Norwegian spring spawning herring. Stock-recruitment of NSSH from data (big red diamonds) and produced by the model (blue small diamonds) using Beverton-Holt recruitment function.

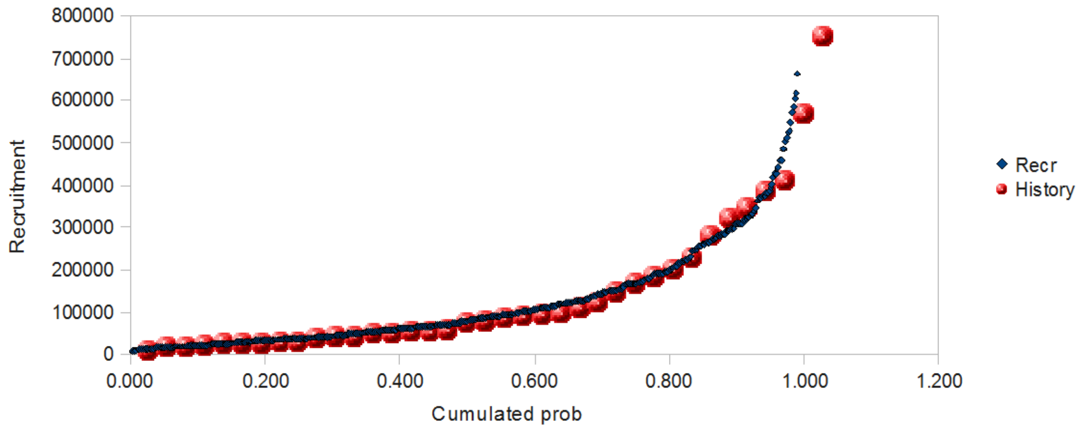

Figure 7.8.2.cumdist. Norwegian spring spawning herring. Cumulative probability of recruitment values of NSSH from the data (red dots) and produced by the model (small blue diamonds) using Beverton-Holt recruitment function.

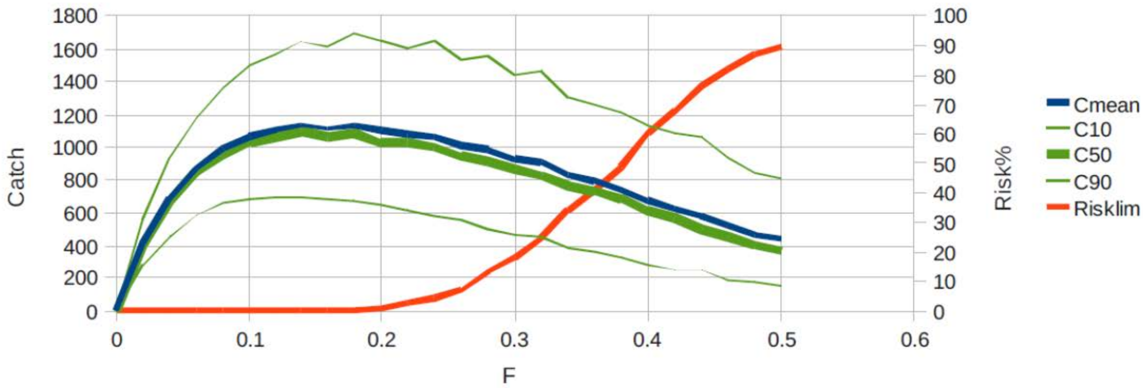

Figure 7.8.2.catch. Norwegian spring spawning herring. Yield (catch) and the probability of the stock being below Blim (2.5. million tonnes) after 50 years at target F for NSSH using Beverton-Holt recruitment function. C10, C50 and C90 show the 10, 50 and 90 percentiles of catch. Risklim shows the probability of stock falling below B_{lim} as a percentage of the model runs. For similar figure for hockey stick recruitment function see WD Skagen 2010.

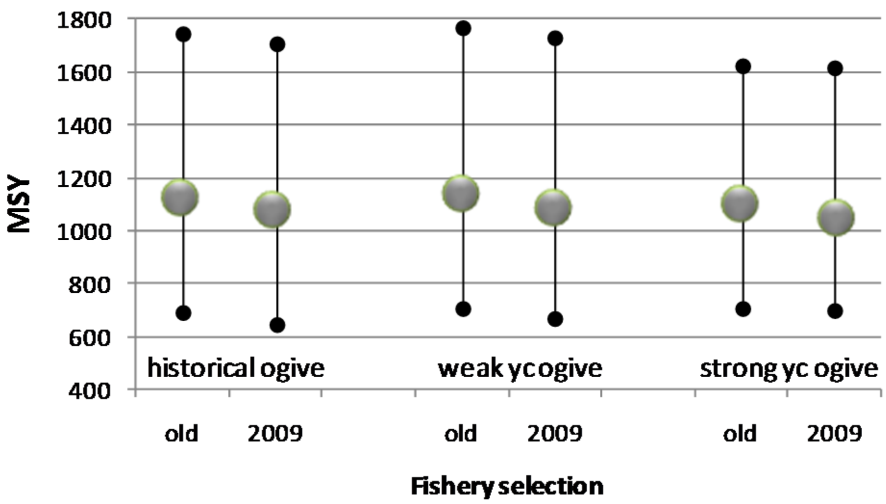

Figure 7.8.2.msyBH. Norwegian spring spawning herring. The MSY for three different maturity ogives and two different fishery selection patterns with 10 and 90 percentiles using Beverton-Holt recruitment function. See text for further details.

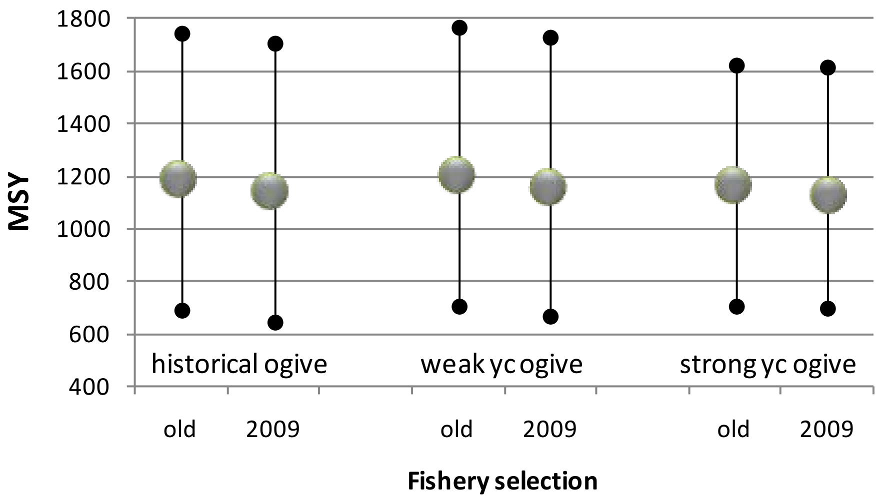

Figure 7.8.2.msyHS. Norwegian spring spawning herring. The MSY for three different maturity ogives and two different fishery selection patterns with 10 and 90 percentiles using hockey stick recruitment function. See text for further details.

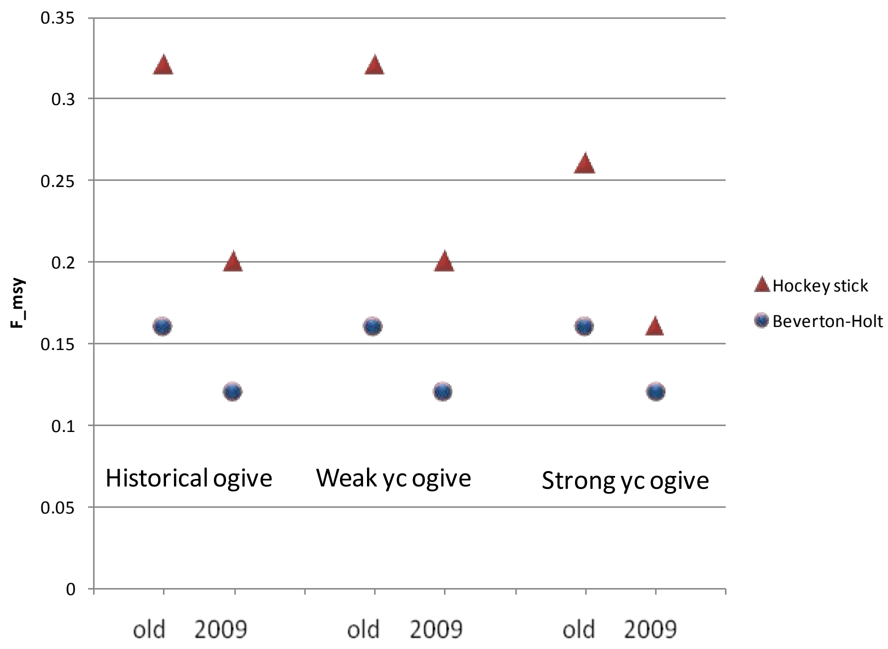

Figure 7.8.2.fmsy. Norwegian spring spawning herring. F_{MSY} for three different maturity ogives and two different fishery selection patterns with Beverton-Holt and hockey stick recruitment function. See text for further details.

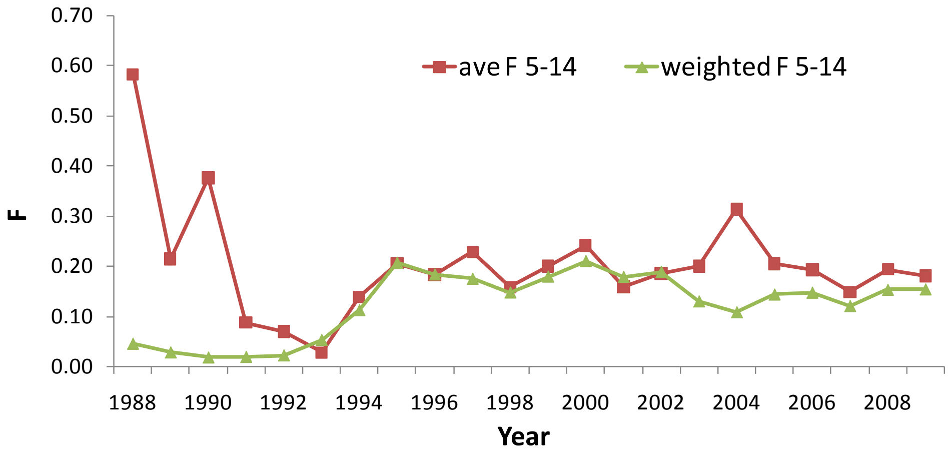

Figure 7.8.2.fvalues. Norwegian spring spawning herring. Unweighted (red squares) and weighted (green triangles) average F values from the current assessment.

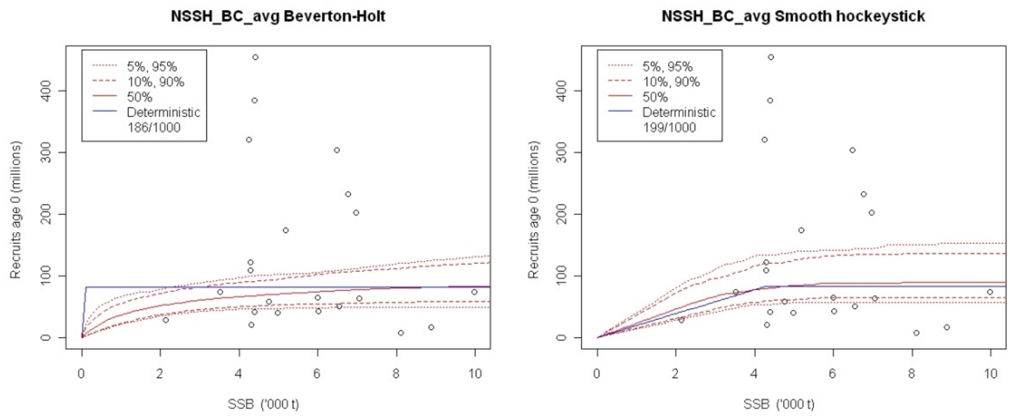

Figure 7.8.2.sr. Deterministic and stochastic (taking into account uncertainty in weights, selectivity and maturity at age) stock recruit relationship fits for the Norwegian spring spawning herring stock. Stock-recruit pairs are from the period 1988-2009.

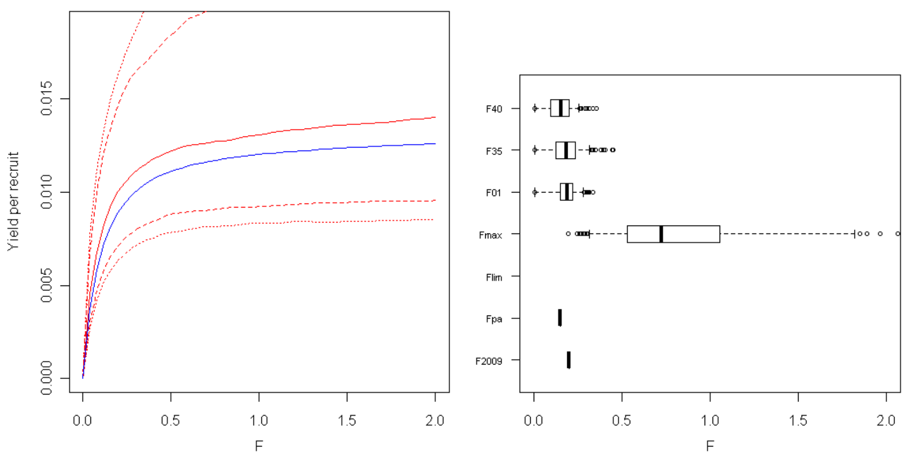

Figure 7.8.2 ypr. The yield-per-recruit (YPR) curve for the Norwegian spring spawning herring stock (left) and resulting stochastic estimates of *F* reference points (right).

G.3. Target reference points

The Coastal States have agreed a target reference point defined at F=0.125. (Note that the average fishing mortality is calculated as a weighted mean over the age groups 5–14 (weighted over abundance).

H. Other Issues not defined

Table B.2.4.1. Norwegian spring spawning herring. Maturity at age information used in the assessments before the 2010 assessments.

	age																
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1950	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1951	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1952	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1953	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1954	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1955	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1956	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1957	0	0	0	0	0	0.5	0.6	1	1	1	1	1	1	1	1	1	1
1958	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1959	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1960	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1961	0	0	0	0.04	0.35	0.68	0.94	1	1	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.11	0.67	1	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0.04	0.03	0.32	0.9	1	1	1	1	1	1	1	1	1	1
1964	0	0	0	0.02	0.06	0.28	0.32	1	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.34	0.35	0.76	1	1	1	1	1	1	1	1	1	1
1966	0	0	0	0.01	0.15	1	0.96	1	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0.01	0.23	1	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0.01	0.76	1	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.62	0.89	0.95	1	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0.06	0.13	0.31	0.17	1	1	1	1	1	1	1	1	1	1
1971	0	0	0	0.1	0.25	0.6	0.9	1	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.1	0.25	0.6	0.9	1	1	1	1	1	1	1	1	1
1973	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1974	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1975	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1
1976	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.73	0.89	1	1	1	1	1	1	1	1	1	1	1	1
1978	0	0	0	0.13	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1979	0	0	0	0.1	0.62	0.95	1	1	1	1	1	1	1	1	1	1	1
1980	0	0	0	0.25	0.5	0.97	1	1	1	1	1	1	1	1	1	1	1
1981	0	0	0	0.3	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1
1982	0	0	0	0.1	0.48	0.7	1	1	1	1	1	1	1	1	1	1	1
1983	0	0	0	0.1	0.5	0.69	0.71	1	1	1	1	1	1	1	1	1	1
1984	0	0	0	0.1	0.5	0.9	0.95	1	1	1	1	1	1	1	1	1	1

1985	0	0	0	0.1	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1
1986	0	0	0	0.1	0.2	0.9	1	1	1	1	1	1	1	1	1	1	1

Table B.2.4.1, cont. Norwegian spring spawning herring. Maturity at age information used in the assessments before the 2010 assessments.

	age																
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1987	0	0	0	0.1	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1988	0	0	0	0.1	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1989	0	0	0	0.1	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1990	0	0	0	0.4	0.8	0.9	0.9	0.9	1	1	1	1	1	1	1	1	1
1991	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1	1	1
1992	0	0	0	0.1	0.2	0.8	1	1	1	1	1	1	1	1	1	1	1
1993	0	0	0	0.01	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1
1994	0	0	0	0.01	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1
1995	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1
1996	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1997	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1998	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
1999	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2000	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2001	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2002	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2003	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2004	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2005	0	0	0	0.1	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1
2006	0	0	0	0	0.9	0.9	1	1	1	1	1	1	1	1	1	1	1
2007	0	0	0	0	0.3	1	1	1	1	1	1	1	1	1	1	1	1

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Table B.3.1.1. Norwegian Spring-spawning herring. Estimates from the acoustic surveys on the spawning stock in February-March. Numbers in millions. Biomass in thousands. Data in black box are used in assessment. There have been corrections due to age readings. ***Survey 1.***

	SURVEY 1							age								Total
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1988		255	146	6805	202										7408	
1989	101	5	373	103	5402	182									6166	
1990	183	187	0	345	112	4489	146								5462	
1991	44	59	54	12	354	122	4148	102							4895	
1992*																
1993*																
1994	16	128	676	1375	476	63	13	140	35	1820					4742	
1995		1792	7621	3807	2151	322	20	1	124	63	2573				18474	3514
1996	407	231	7638	11243	2586	957	471	0	0	165	0	2024			25722	4824
1997*																
1998			381	1905	10640	6708	1280	434	130	39	0	64	0	915	22496	5360
1999	106	1366	337	1286	2979	11791	7534	1912	568	132	0	0	392	437	28840	7213
2000	1516	690	1996	164	592	1997	7714	4240	553	71	3	0	6	24	19566	4913
2001**																
2002**																
2003**																
2004**																
2005	103	281	811	3310	7545	10453	887	563	159	122	610	1100	686		26649	6501

2006	13	75	10167	684	1103	4540	4407	133	47	11	113	120	323	135	21871	4858
2007	109	534	2097	14575	952	592	3270	3092	263	276	20	285	189	628	26882	6004
2008	10	145	3517	3749	15066	972	612	2410	2374	426	136	121	90	171	29798	7244

*** No estimate due to poor weather conditions.**

**** No surveys.**

Table B.3.2.1 Norwegian Spring-spawning herring. Estimates obtained on the acoustic surveys in the wintering areas in November-December. Numbers in millions. Data in black box are used in assessment. There have been corrections due to age readings. *Survey 2*.

SURVEY 2									age					Total	
year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	total	biomass
1992		36	1247	1317	173	16	208	139	3742	69					6947	
1993	72	1518	2389	3287	1267	13	13	158	26	4435					13178	
1994		16	3708	4124	2593	1096	34	25	196	29	3239				15209	
1995	380	183	5133	5274	1839	1040	308	19	13	111	39	907			15246	
1996		1465	3008	13180	5637	994	552	92	0	7	41	15	393		25384	
1997	9	73	661	1480	6110	4458	1843	743	66	0	0	64	0	904	16411	
1998	65	1207	441	1833	3869	12052	8242	2068	629	111	14	0	40	573	31144	
1999	74	159	2425	296	837	2066	6601	4168	755	212	0	15	0	146	17754	
2000	56	322	1522	5260	165	497	1869	4785	3635	668	205	0	0	11	18995	
2001	362	522	3916	1528	2615	82	338	864	3160	2216	384	127	0	1	16115	
2002*	7	50	276	1659	624	1029	32	188	516	1831	911	184	0	0	7307	
2003**	586	406	2167	10670	13237	1047	678	41	134	301	1214	502	10	37	31030	
2004**	257	6814	1123	1596	5334	6731	363	280	37	42	187	761	392	83	24000	
2005	61	352	7173	465	685	2030	3101	177	190	57	46	184	476	327	15325	
2006	940	7785	3712	21320	1153	340	2879	4851	4	23	713	4	150	58	43778	
2007	1233	343	4161	2407	6213	226	288	695	694	0	43	0	126	188	16617	3660

*** Much of the youngest yearclasses (-98,-99) wintered outside the fjords this winter and are not included in the estimate**

**** In 2003-2004 a combined estimate from the Tysfjord, Ofotfjord and oceanic areas off Vesterålen/Troms.**

Table B.3.3.1 Norwegian spring spawning herring. Estimates obtained on the acoustic surveys in the wintering areas in January. Numbers in millions. Data in the black box are used in the assessment. There have been corrections due to age readings. ***Survey 3.***

SURVEY 3														age	
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1991	90	220	70	20	180	150	5500	440							6670
1992		410	820	260	60	510	120	4690	30						6900
1993		61	1905	2048	256	27	269	182	5691	128					10567
1994	73	642	3431	4847	1503	102	29	161	131	3679					14598
1995		47	3781	4013	2445	1215	42	24	267	29	4326				16189
1996		315	10442	13557	4312	1271	290	22	25	200	58	1146			31638
1997*															-
1998	214	267	1938	4162	9647	6974	1518	743	16	4	0	33	7	462	25985
1999**	0	1358	199	1455	4452	12971	7226	1876	499	16	16	0	156	220	30444

*** No estimate due to poor weather conditions.**

**** No surveys since 1999.**

Table B.3.4.1. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in May/June. No survey in 2003, 1990-2002. See footnotes. Data in black box used in the assessment except the yellow highlighted cell. ***Survey 4.***

	survey 4	age			
Year	1	2	3	4	5
1991	24.3	5.2			
1992	32.6	14	5.7		
1993	102.7	25.8	1.5		
1994	6.6	59.2	18	1.7	
1995	0.5	7.7	8	1.1	
19961	0.1	0.25	1.8	0.6	0.03
19972	2.6	0.04	0.4	0.35	0.05
1998	9.5	4.7	0.01	0.01	0
1999	49.5	4.9	0	0	0
2000	105.4	27.9	0	0	0
2001	0.3	7.6	8.8	0	0
2002	0.5	3.9	0	0	0
20033					
20043					

2005	23.3	4.5	2.5	0.4	0.3
2006	3.7	35.0	5.3	0.87	0
2007	2.1	3.7	12.5	1.9	0
2008[4]	0.043	0.38	0.2	0.28	0
2009	0.191	0.845	2.180	2.643	1.213

[1] Average of Norwegian and Russian estimates

[2] Combination of Norwegian and Russian estimates as described in 1998 WG report, since then only Russian estimates

[3] No surveys

[4] Not a full survey

Table B.3.4.2. Norwegian spring spawning herring. Estimates from the international acoustic surveys on the feeding areas in the Norwegian Sea in May. Numbers in millions. Biomass in thousands. Data in black box are used in assessment. There have been corrections due to age readings. *Survey 5.*

	survey 5									Age							Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1996	0	0	4114	22461	13244	4916	2045	424	14	7	155	0	3134			50514	8532
1997	0	0	1169	3599	18867	13546	2473	1771	178	77	288	190	60	2697		44915	9435
1998	24	1404	367	1099	4410	16378	10160	2059	804	183	0	0	35	0	492	37415	8004
1999	0	215	2191	322	965	3067	11763	6077	853	258	5	14	0	158	128	26016	6299
2000	0	157	1353	2783	92	384	1302	7194	5344	1689	271	0	114	0	75	20758	6001
2001	0	1540	8312	1430	1463	179	204	3215	5433	1220	94	178	0	0	6	23274	3937
2002	0	677	6343	9619	1418	779	375	847	1941	2500	1423	61	78	28	0	26089	4628
2003	32073	8115	6561	9985	9961	1499	732	146	228	1865	2359	1769		287	0	75580	6653
2004	0	13735	1543	5227	12571	10710	1075	580	76	313	362	1294	1120	10	88	48704	7687
2005	0	1293	19679	1353	1765	6205	5371	651	388	139	262	526	1003	364	115	39114	5109
2006	0	19	306	14560	1396	2011	6521	6978	679	713	173	407	921	618	243	35545	9100
2007	0	411	2889	5877	20292	1260	1992	6780	5582	647	488	372	403	1048	1010	49051	12161
2008	0	1193	587	8332	8270	16345	1381	1920	3958	2500	416	242	159	217	408	45928	9996
2009	202	906	2980	2754	14292	9487	11629	1472	1253	2587	1357	267	183	60	258	49687	10700

Table B.3.5.1. Norwegian spring-spawning herring. Abundance indices for 0-group herring 1980-2008 in the Barents Sea, August-October. ***This index has been recalculated since 2006, these are the new values. Survey 7.***

survey 7	
Year	Abundance index
1980	4
1981	3
1982	202
1983	40557
1984	6313
1985	7237
1986	7
1987	2
1988	8686
1989	4196
1990	9508
1991	81175
1992	37183
1993	61508
1994	14884
1995	1308
1996	57169
1997	45808
1998	79492
1999	15931
2000	49614
2001	844
2002	23354
2003	28579
2004	133350
2005	26332
2006	66819
2007	22481
2008	15727

Table B.3.5.2. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in August-October. Data in black boxes used in the assessment. *Survey 6.*

survey 6			
	Age		
Year	1	2	3
2000	14.7	11.5	0
2001	0.5	10.5	1.7
2002	1.3	0	0
2003	99.9	4.3	2.5
2004	14.3	36.5	0.9
2005	46.4	16.1	7.0
2006	1.6	5.5	1.3
2007	3.9	2.6	6.3
2008	0.03	1.6	4.0

Table B.3.6.1.. Norwegian Spring-spawning herring. The indices for herring larvae on the Norwegian shelf for the period 1981-2009 ($N*10^{-12}$). Data in black box are used in the assessment. ***Survey 8.***

survey 8		
Year	Index1	Index 2
1981	0.3	
1982	0.7	
1983	2.5	
1984	1.4	
1985	2.3	
1986	1	
1987	1.3	4
1988	9.2	25.5
1989	13.4	28.7
1990	18.3	29.2
1991	8.6	23.5
1992	6.3	27.8
1993	24.7	78
1994	19.5	48.6
1995	18.2	36.3
1996	27.7	81.7
1997	66.6	147.5
1998	42.4	138.6
1999	19.9	73
2000	19.8	89.4
2001	40.7	135.9
2002	27.1	138.6
2003*	3.7	18.8
2004	56.4	215.1
2005	73.91	196.7
2006	98.9	389.0
2007**	90.6	
2008	107.9	393.3
2009***	8.4	53.8

Index 1. The total number of herring larvae found during the cruise.

Index 2. Back-calculated number of newly hatched larvae with 10% daily mortality. The larval age is estimated from the duration of the yolksac stages and the size of the larvae.

*** Poor weather conditions and survey was late in April**

**** only representative for the area 62-66°N**

*****Likely that spawning was particularly early in 2009**

Table B.3.7.1. Norwegian spring spawning herring. Acoustic estimates from the coordinated ecosystem survey in Norwegian Sea and adjoining waters in July-August. Numbers in millions. Biomass in thousands. ***Survey 9.***

survey 9						Age									Total	
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
2009	0	415	4136	3522	12448	7479	12362	1223	2144	1761	410	0	157	75	756	46888	13603
2010	543	327	1309	2631	2500	10141	6619	6471	1163	2310	804	422	166	87	144	35637	10717

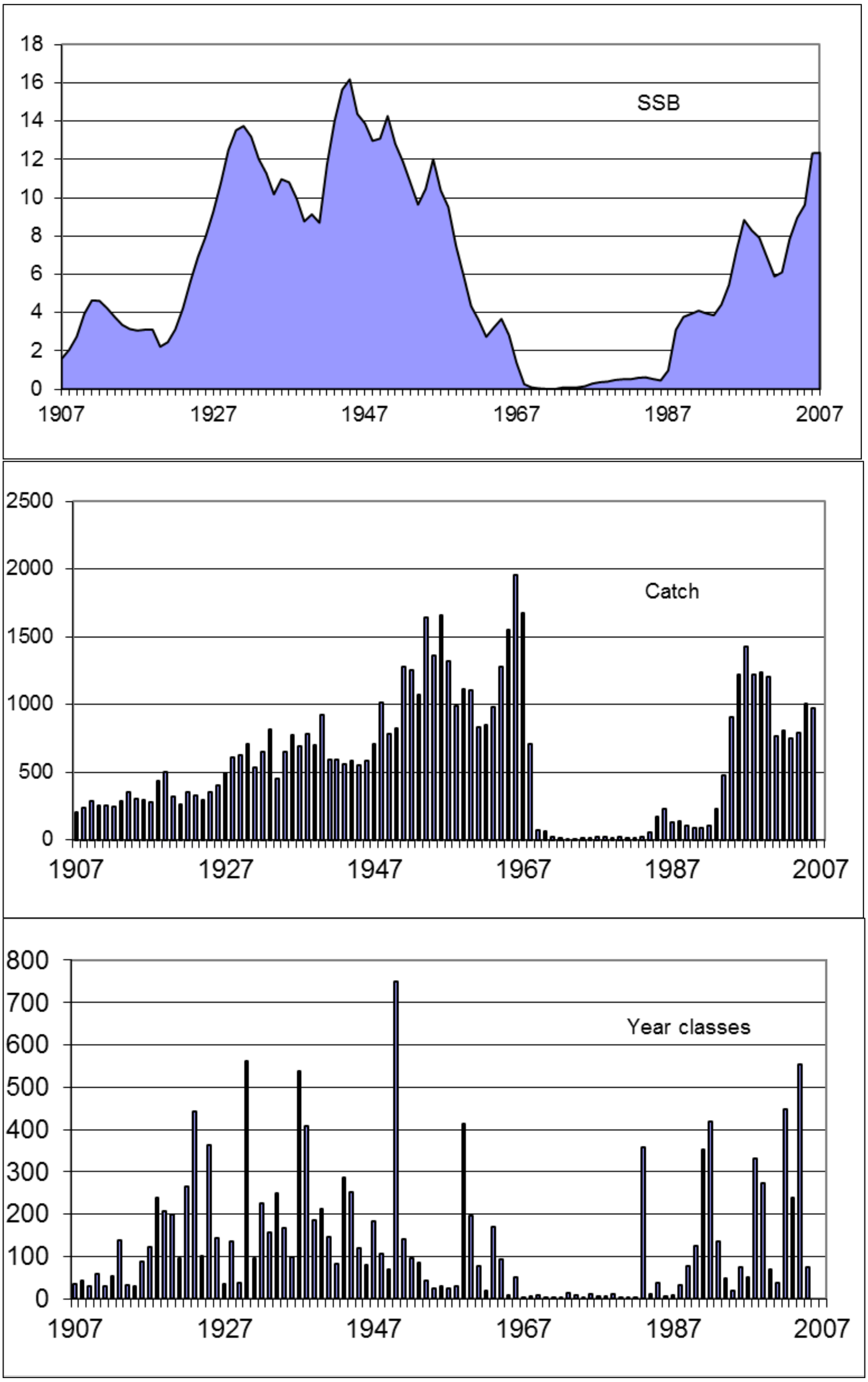

Figure A.1.1.1. Norwegian spring spawning herring. Long term trends in spawning stock, catches and recruits (1907-1988 from Toresen and Østvedt; 1989-2007 from WGNPBW 2007).

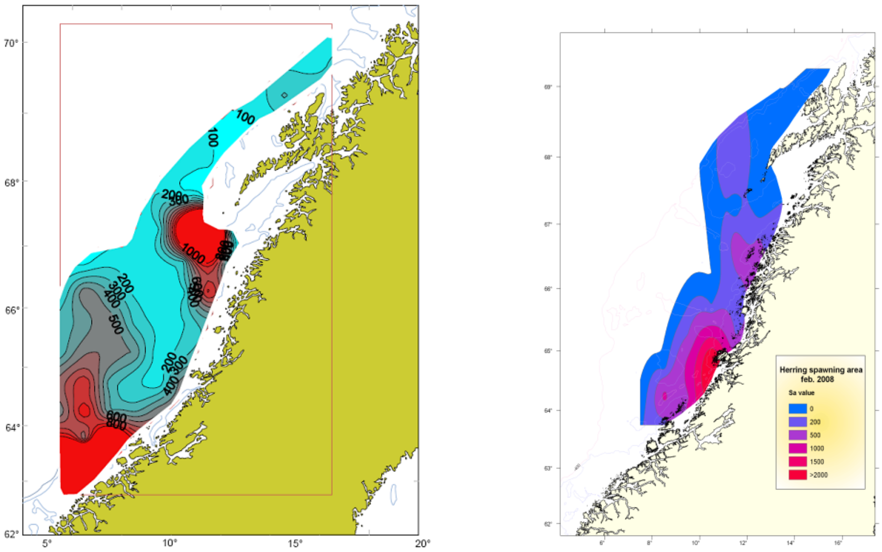

Figure B.3.1.1. NSSH Acoustic survey on spawning grounds in February March, 2007 (left) and 2008 (right).

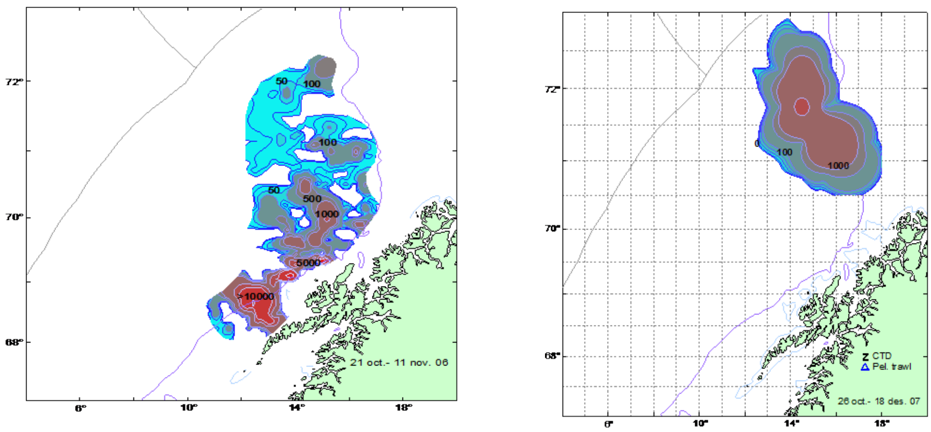

Figure B.3.2.1. NSSH Acoustic survey in November/December 2006 (left panel here) and 2007 (right panel).

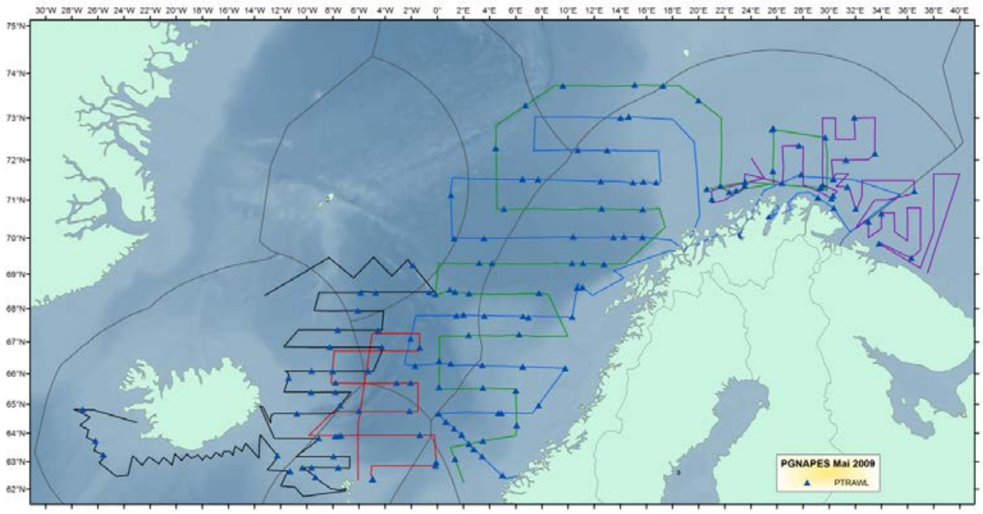

Figure B.3.4.1. Cruise tracks during the International North East Atlantic Ecosystem Survey in April-May 2009 and location of trawl stations.

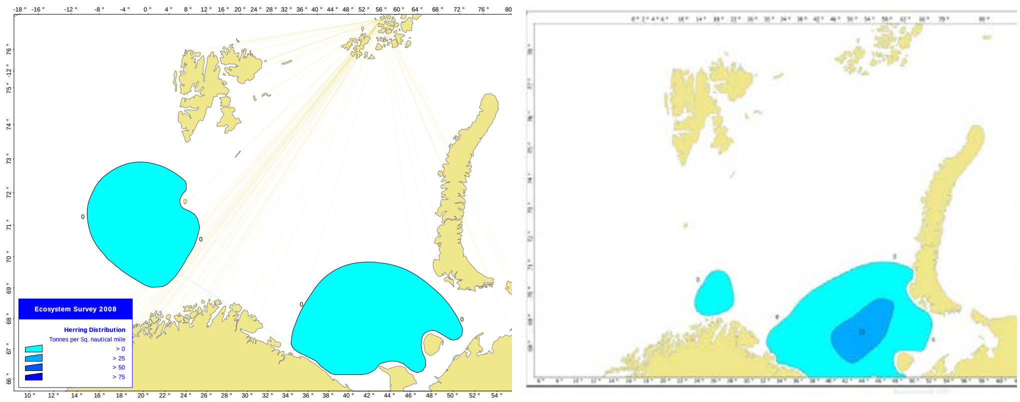

Figure B.3.5.1. Estimated total density of herring (tonnes/nautical mile²) in August-September 2008 (left panel) and 2007 (right panel).

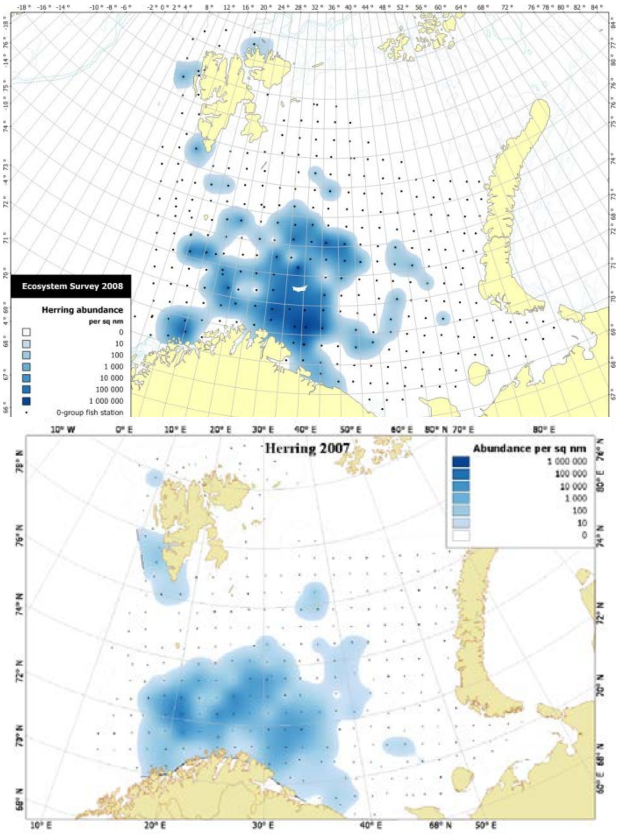

Figure B.3.5.2. NSSH O–group surveys in August/September in the Barents Sea in 2008 (left panel) and 2007 (right panel).

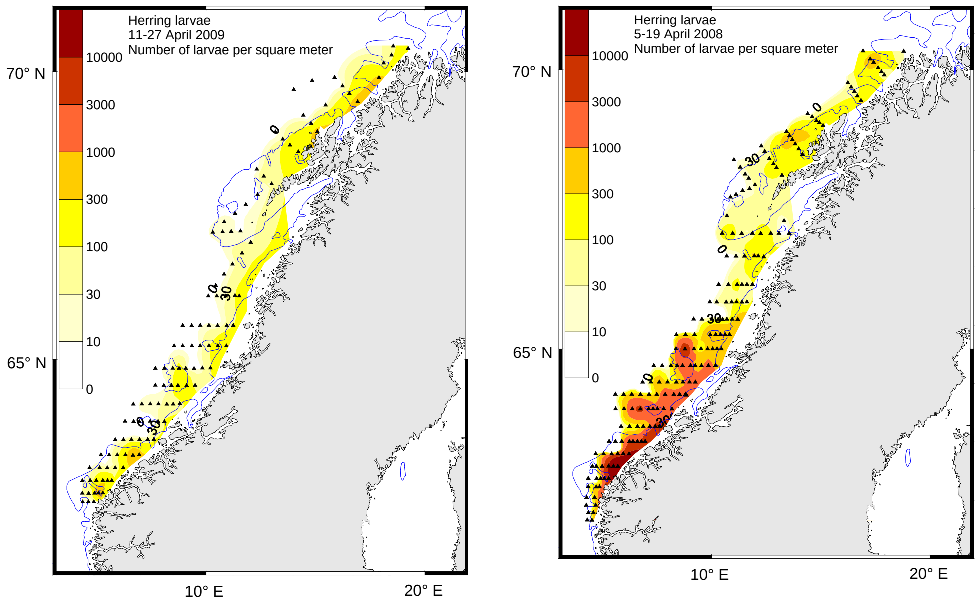

Figure B.3.6.1. NSSH. Distribution of herring larvae on the Norwegian shelf in 2009 (left panel) and 2008 (right panel). The 200 m depth line is also shown.

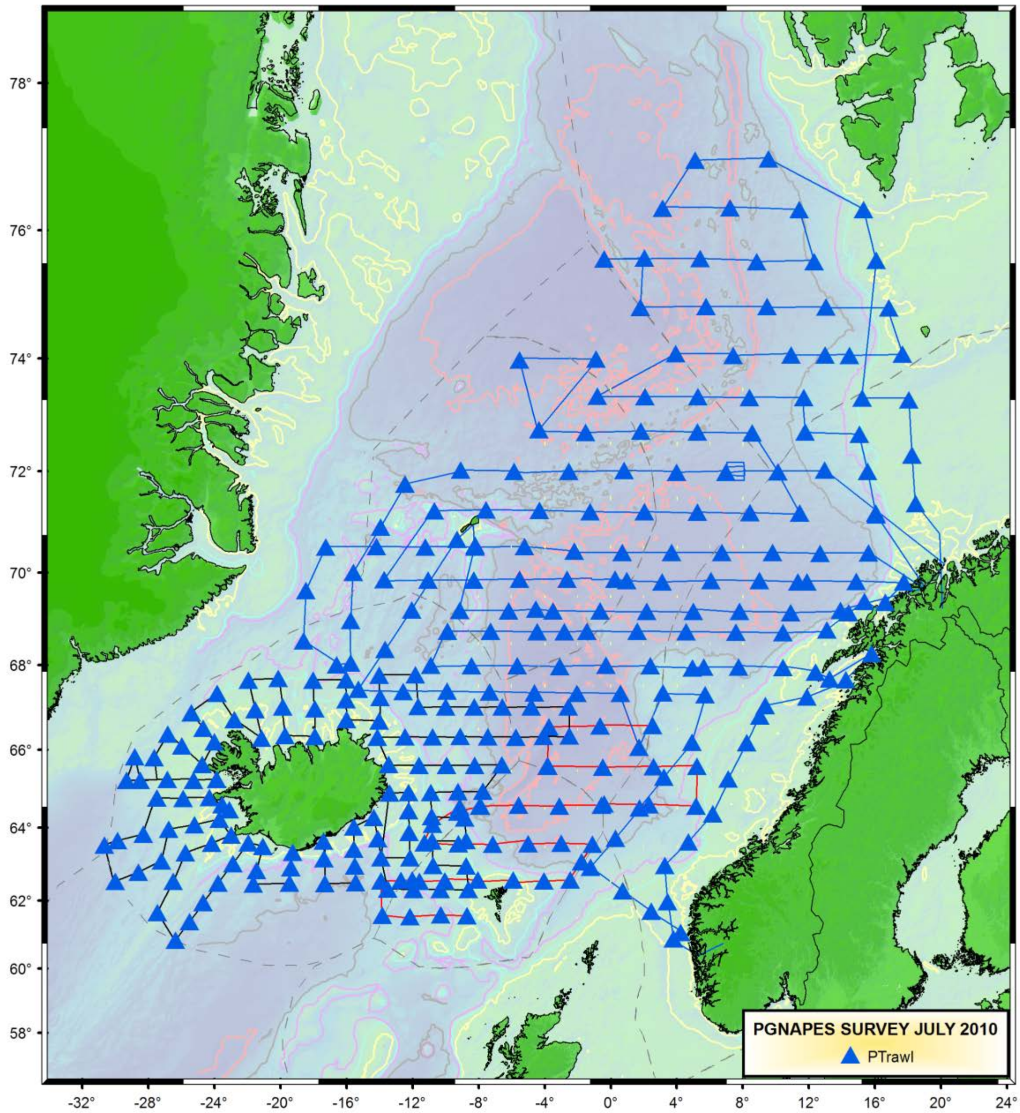

Figure B.3.7.1. Cruise tracks during the coordinated ecosystem survey in Norwegian Sea and adjoining waters in July-August 2010 and location of trawl stations.

Table 9.4.5.3 Herring in the Northeast Atlantic (Norwegian spring-spawning herring). Summary of the stock assessment. Data prior to 1988 are from the 2006 assessment year.

Year	Recruitment	SSB	Landings	F weighted
	Age 0			Ages 5-14
	thousands	tonnes	tonnes	
1950	751000000	14200000	826000	0.0584
1951	146000000	12500000	1280000	0.0697
1952	96600000	10900000	1250000	0.0728
1953	86100000	9350000	1070000	0.0663
1954	42100000	8660000	1640000	0.1130
1955	25000000	9270000	1360000	0.0783
1956	29900000	10900000	1660000	0.1100

Year	Recruitment	SSB	Landings	F weighted
	Age 0			Ages 5-14
	thousands	tonnes	tonnes	
1957	25400000	9650000	1320000	0.1030
1958	23100000	8690000	986000	0.0787
1959	412000000	7180000	1110000	0.1130
1960	198000000	5850000	1100000	0.1360
1961	76100000	4390000	830000	0.1040
1962	19000000	3440000	849000	0.1460
1963	169000000	2670000	985000	0.2530
1964	93900000	2530000	1280000	0.2260
1965	8490000	3060000	1550000	0.2780
1966	51400000	2800000	1960000	0.6960
1967	3950000	1470000	1680000	1.5200
1968	5190000	344000	712000	3.4900
1969	9780000	145000	67800	0.5900
1970	661000	71000	62300	1.3200
1971	236000	32000	21100	1.5300
1972	957000	16000	13200	1.5000
1973	12900000	85000	7020	1.1700
1974	8630000	91000	7620	0.1140
1975	2970000	79000	13700	0.1900
1976	10100000	138000	10400	0.1060
1977	5100000	286000	22700	0.1110
1978	6200000	358000	19800	0.0434
1979	12500000	388000	12900	0.0238
1980	1470000	471000	18600	0.0341
1981	1100000	504000	13700	0.0215
1982	2340000	503000	16700	0.0200
1983	343000000	575000	23100	0.0291
1984	11500000	602000	53500	0.0903
1985	36600000	515000	170000	0.3790
1986	6040000	437000	225000	1.0700
1987	9090000	926000	127000	0.4040
1988	25724000	2768000	135301	0.045
1989	73988400	3409000	103830	0.029
1990	109705800	3702000	86411	0.022
1991	320875600	3877000	84683	0.023
1992	383921700	3767000	104448	0.027
1993	121890400	3641000	232457	0.064
1994	42242100	4122000	479228	0.129
1995	18643900	4976000	905501	0.229
1996	57789400	6545000	1220283	0.192
1997	50575900	7887000	1426507	0.180
1998	282407700	7290000	1223131	0.153
1999	227356600	6852000	1235433	0.186

Year	Recruitment	SSB	Landings	F weighted
	Age 0			Ages 5-14
	thousands	tonnes	tonnes	
2000	54030800	5837000	1207201	0.213
2001	35695300	4794000	766136	0.180
2002	568142000	4928000	807795	0.184
2003	185261300	6298000	789510	0.114
2004	344513300	7149000	794066	0.094
2005	53536700	7715000	1003243	0.128
2006*	90770000	11580000	968958	0.131
2007*	30990000	11836000	1266993	0.098
2008**	103000000	12437000	1545656	0.125
2009**	103000000	13300000		
Average	100457748	4646433	690524	0.3220

*** Recruitment value has been replaced in the forecast by RCT estimate.**

**** GM mean 1989-2005**