ICES WKHERMAT REPORT 2010

ICES ADVISORY COMMITTEE

ICES CM 2010/ACOM:51

REF. PGCCDBS

Report of the Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT)

1–3 March 2010

Bergen, Norway

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Recommended format for purposes of citation:

ICES. 2010. 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. 47 pp.

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Executive summary

This report presents the result from a Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT), held in Bergen (Norway), 1-3 March 2010. The workshop was chaired by Erling Kåre Stenevik (Norway) and 10 participants from 5 countries attended the workshop.

The workshop met its Terms of References which were to

a) compare back-calculated maturity at age estimates in Norwegian spring spawning herring with annual estimates derived directly from the ecosystem survey in May.
b) develop guidelines for sampling data on maturity at age in Norwegian spring spawning herring, for use in assessment, in accordance with the PGCCDBS guidelines for collecting maturity data and maturity ogive estimation for stock assessment purpose (see PGCCDBS Report 2009, Annex 10).

Data on maturity ogive from three different sources were presented and discussions on strengths and weaknesses of the different data sources took up most of the time. The three different data sources were: a) maturity ogive used in assessment, b) survey data on maturity ogive from the Ecosystem survey in May 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 by ICES 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 are not explained.

The May survey may potentially provide data to construct updated maturity ogives. The survey 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 some potential problems were discovered. The deviation of a maturity ogive from the survey data compared to back-calculations appeared to be problematic. There appear to be differences in the catchability in the survey between the Norwegian Sea (where most of the mature fish is distributed) and the Barents Sea (where most of the immature fish is found). 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 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 the assessment 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.

1 Opening of the meeting

The meeting was opened by the Chair and all participants were welcomed and introduced.

2 Adoption of the agenda

The agenda was presented and since there was no comments it was adopted as presented (Annex 2).

3 Background of the meeting

Except for the 2002 year class, the proportion mature at age used in assessment for Norwegian spring spawning herring (NSSH) has generally been the same over the last ten years. Different assumptions made on the maturation of the abundant 2002 year class, however, lead to spawning stock biomass (SSB) estimates of NSSH which differed up to 1 million tonnes. There is no documentation of the values used in recent years. During the benchmark assessment in 2008, WGWIDE recommended that effort should be put into updating estimates on proportion mature at age for NSSH using back-calculation techniques and compare these with direct measurements on proportion mature at age from the Ecosystem survey in the Nordic Seas coordinated by PGNAPES (May survey). Maturity estimates from a back calculation analysis would allow updating the ogives used in the assessment for the historical period. However, data from back calculation studies do not provide information of maturation in recent years and these have to be derived from sampling programmes.

Previously, maturity at age was sampled in two surveys, one of which stopped in 2008. Alternative values of proportion mature at age from the May survey were presented to WGWIDE in 2009. The WG discussed this approach and considered it to be interesting. However, a problem was identified regarding the sample size, particularly of the young age-classes (age 3). The number of samples of this age class in the survey was relatively low and the WG decided to use the same proportion mature at age as last year. However, the WG recommended exploring this further and it was recommended that the work on maturity ogive is of such importance that it should be evaluated by an expert group outside the WG.

It was decided to have an ICES workshop on maturity estimation in NSSH, 1-3 March 2010 in Bergen chaired by Erling Kåre Stenevik (Norway).

The ToRs are given below:

2009/2/ACOM53 A **Workshop on estimation of maturity ogive in Norwegian spring spawning herring** (WKHERMAT), chaired by Erling K. Stenevik, Norway will be established and will meet in Bergen, Norway, 1–3 March 2010 to:

a) compare back-calculated maturity at age estimates in Norwegian spring spawning herring with annual estimates derived directly from the ecosystem survey in May.
b) develop guidelines for sampling data on maturity at age in Norwegian spring spawning herring, for use in assessment, in accordance with the PGCCDBS guidelines for collecting maturity data and maturity ogive estimation for stock assessment purpose (see PGCCDBS Report 2009, Annex 10).

WKHERMAT will report by 30 March 2010 for the attention of the ACOM.

4 Data sources used by WKHERMAT

Several sources of data were made available to the WK and these are presented below.

4.1 Working group data used in assessment

The maturity matrix used by ICES goes back to 1907. However, prior to 1950 a fixed maturity ogive has been used in accordance with the VPA run by Toresen and Østvedt (2000). Only the data after 1950 were considered by the Workshop. The maturity-at-age values used in assessment is presented in Figure 4.1.1 and Annex 4. The figure shows several periods of constant maturity-at-age. There are also periods with large or small annual changes. Documentation on the source of information and the justification of changes are scarce (literature and a number of old WG reports were checked by WKHERMAT). The WK found no documentation to specify whether the assessment ogives had been based on combined data from both sexes or on females alone. However, personal communication from previous WG participants led WKHERMAT to conclude that the ogives used in assessment have been based on combined data. The WK assumed that the major source of information used by ICES would probably come from surveys on the wintering and spawning grounds in the Norwegian Sea as indicated in some of the WG reports. It is also likely that no information from the Barents Sea was available, since surveys in this area have only been carried out in recent years. It is likely that for some periods no actual maturity material has been considered - such as recent years - or that the available information had not lead to a decision to change the maturity-ogive in some periods. 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 are not explained.

The maturity ogive for the large 2002 year-class was treated differently than other year-classes in the assessment (see Figure 4.1.1). This year-class has had the Norwegian Sea as nursery area favoring higher growth rate compared to previous large year-classes using the Barents Sea as nursery area. Based on that, adjustments to the maturity ogive for this year-class were done by the WG in 2005-2007. Proportion mature at ages 3-5 was increased from 0, 0.3 and 0.9 to 0.1, 0.9 and 1, respectively. This was done based on proportion mature calculated from surveys in the wintering area in November and in the Norwegian Sea in May. WKHERMAT compared estimates of maturity ogives based on the May survey for the 2002 year class with neighboring year-classes. It was shown that estimates of maturity at age 4 from the May survey are high also for the neighboring year-classes and it is likely that the May survey overestimate maturity at age 4 (see chapter 4.2). Back-calculation of maturity at age 4 for the 2002 year-class (see chapter 4.3) is much lower than the values based on surveys. WKHERMAT therefore concluded that the adjustments of maturity at age for the 2002 year-class is not justified and recommends that they are reconsidered by WGWIDE.

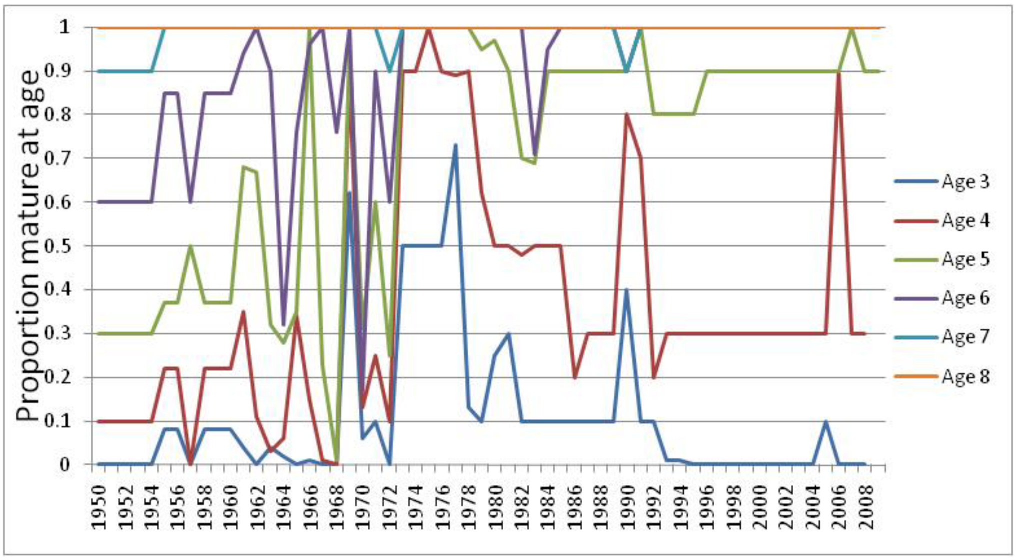

Figure 4.1.1. Maturity-at-age for Norwegian spring spawning herring (1950-2009) used in assessment by ICES.

4.2 Survey data

A second source of data available for the workshop was data obtained from the International Ecosystem Survey in the Nordic Seas in May coordinated by PGNAPES. Since 2005, this survey has covered the NSSH stock both in the feeding areas of the mature part of the stock in the Norwegian Sea and in the Barents Sea which is the most important area for the immature part of the stock. An exception is 2008, when the Barents Sea was not covered. A typical cruise track from the survey is shown in Figure 4.2.1. The survey area is divided into three sub-areas (Figure 4.2.2) and numbers of fish at age considered to be mature (maturity stages 3-8) and immature (stages 1-2) from the three areas (Barents Sea, northeast Norwegian Sea and southwest Norwegian Sea) were weighted by the total acoustic estimate of fish at age in the respective areas and then combined to calculate proportion mature at age from the whole distribution area of NSSH. The results are presented in figure 4.2.3 and Annex 4. Additionally, maturity ogives for each area are presented in Annex 4 for comparison of ogives among the three areas. Compared to the back-calculated maturity at age 4 (0.1-0.3), the maturity at age 4 was considerably higher (0.5-0.9) when estimated from the May survey for the same years (2005, 2006, and 2007). The reason for this may be that the survey overestimated maturity at age for recruiting year-classes. Different catchability between young and older fish and between immature and mature components of the same age-class probably exists and this needs to be addressed before the survey can be used to produce maturity ogives for assessment. Suggestions for improvements are presented in chapter 5.2.

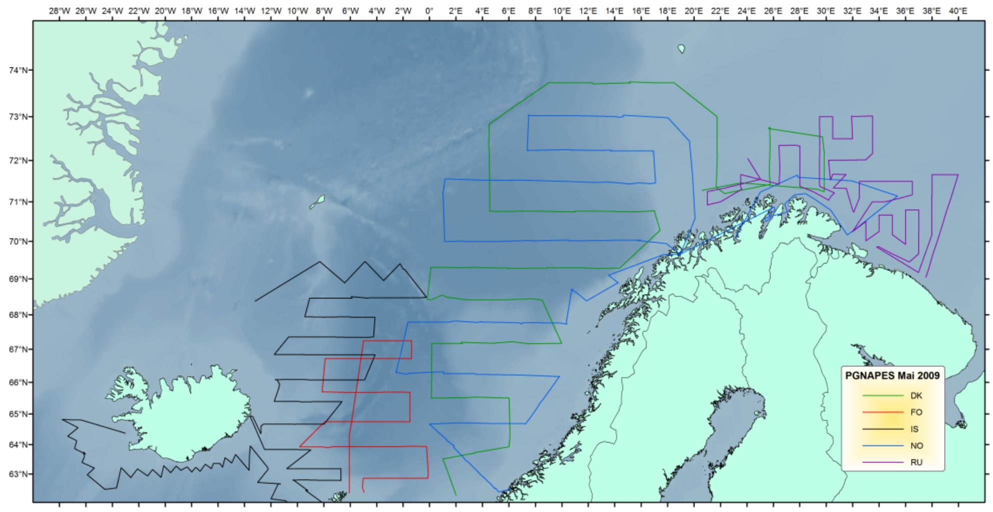

Figure 4.2.1. Cruise tracks during the International Ecosystem Survey in the Nordic Seas in April-May 2009.

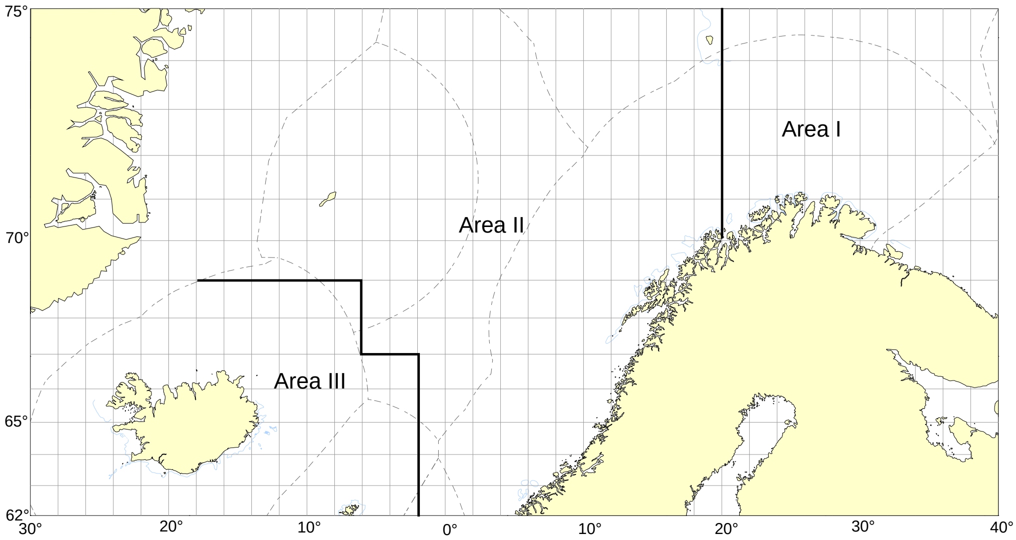

Figure 4.2.2. Areas defined for acoustic estimation of blue whiting and Norwegian spring spawning herring in the Nordic Seas.

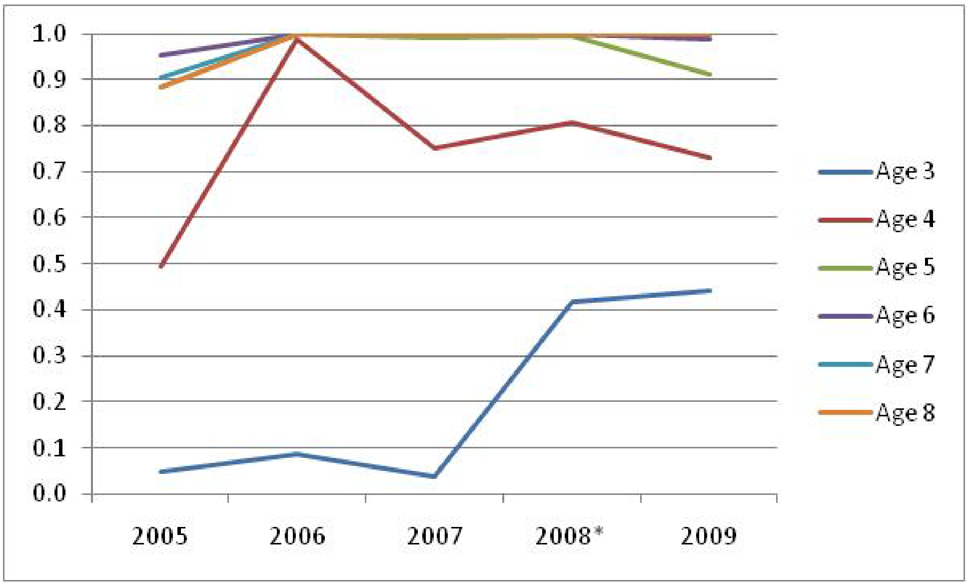

Figure 4.2.3. Maturity-at-age for Norwegian spring spawning herring estimated from the May survey (2005-2009). There was no coverage in the Barents Sea in 2008

4.3 Back-calculated data

Engelhard *et al.* (2003) and Engelhard and Heino (2004) have developed a method to back-calculate age at maturation for individual herring based on scale measurements and used this to construct maturity ogives for the year classes 1930-1992. Their method involves two steps. First, a discriminant analysis (alternatively neural networks) is used to predict age of maturity for individual fish based on scale measurements (Figure 4.3.1) of mature fish sampled on the spawning ground surveyed in January-March (Engelhard *et al*., 2003). This method involves the measurements of the total radius of the scale and of the radius of each annual growth ring (up to the 9th ring).

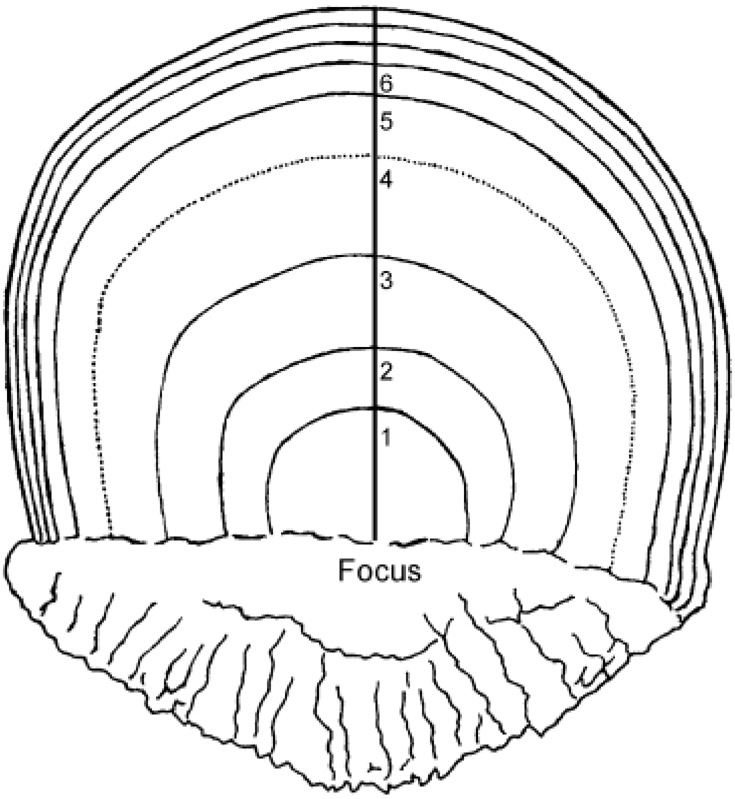

Figure 4.3.1. Lateral scale from a 9-year-old herring caught in February. The widths of annual growth rings are measured along the imaginary line indicated, which runs from the focus of the scale to its periphery. Note that this scale shows three wide coastal rings separated by sharp winter rings; two wide oceanic rings separated by a diffuse winter ring; and four narrow spawning rings separated by sharp winter rings. Therefore, the age at maturation is 5. From Engelhard *et al.* (2003).

The second step is to calculate maturity ogives using Gulland's method which is based on the relative abundance of recruit and repeat spawners of given age in the population and can therefore only be used with data on mature fish (Engelhard and Heino, 2004). An iterative estimation procedure is started in the year during which the last fish of a year-class considered have reached maturity (normally at age 9 years for NSSH). The immature part of that year-class in the previous year therefore consisted of fish that would all mature one year later, and is thus equal to the proportion of recruit spawners among the combined sample of recruit and repeat spawners one year later. By back-calculation, the proportion of immature fish can thus be estimated for all previous ages relevant for maturation.

For WKHERMAT this method was used, and the data series was extended to include recent data (Georg Engelhard pers. comm., Cefas, Lowestoft, UK). Originally, only data from surveys on the spawning grounds were used. However, this survey has been discontinued and in order to extend the time series to include recent years, we used data from the entire IMR data set on Norwegian spring spawning herring including data from both surveys and commercial catches. Based on this we could back-calculate maturity ogives from the year-classes back to 1929. These data were then rearranged to give annual maturity ogives. Maturity-at-age for the years 1950-2009 is presented in figure 4.3.2. For recent year classes that had not fully matured, long term averages for back-calculated maturity-at-age was used.

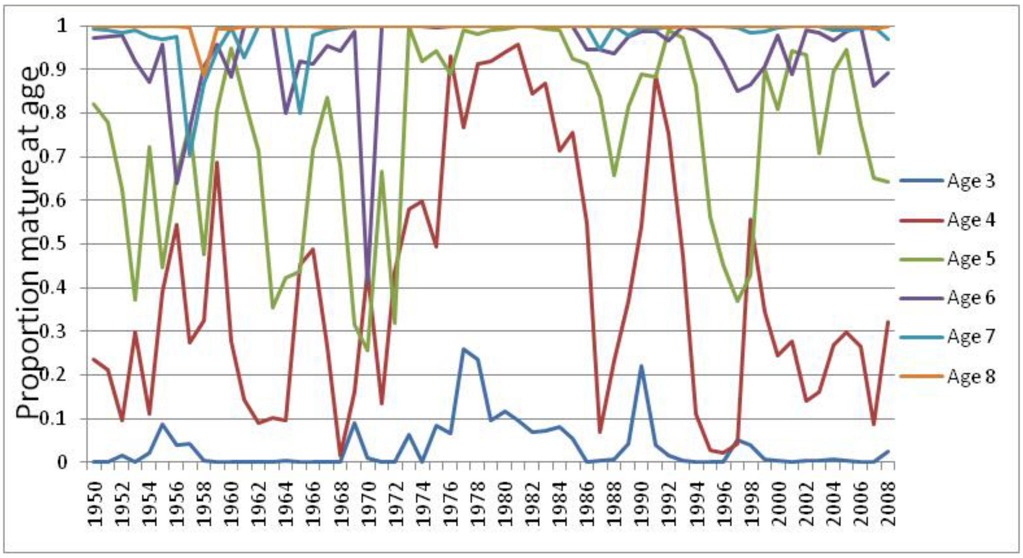

Figure 4.3.2. Back-calculated maturity-at-age for Norwegian spring spawning herring (1950-2009) using Gulland's method.

This method has a number of advantages to the traditional methodology of determining the maturity status of fish each year and a number of potential problems that need to be investigated. One major advantage is the ability to estimate annually varying maturity ogives for NSS herring back in time. In addition, it provides an insight in to how the maturity ogives of very large and small year classes have really changed under high and low densities. These data can also be utilised for further investigations, such as whether there are sex specific variations in maturity ogives.

There are a number of underlying assumptions that need further investigation, work that could not be carried out during the Workshop due to either time constraints or that G. Englehard was not able to attend. The results are essentially assessing the maturity schedules of the survivors. There is a potential bias in the results if there is a higher mortality on first time spawners through either fishing pressure or energetic costs of spawning. Likewise, since there is a targeted fishing pressure on the spawning grounds there is an increasing probability of mortality with each spawning event. Added to this is the potential bias from Lee's phenomenon (Lee 1912; Ricker 1975) whereby the survivors tend to be the slower growers and presumably are the later maturing fish. One way to test this is to successively remove older fish from the analysis and determine if there is a shift toward earlier A_{50} in the maturity ogives. If so then a decision needs to be made on the appropriate age range to use for the analyses.

A further disadvantage is that this methodology cannot be used for the most recent years since it relies on a year class being fully mature before it can enter the analysis. Other methodologies will need to be utilised e.g. survey data or models for the most recent five years.

One point that is still unclear is the exact interpretation of the rings. In general the change in ring widths signal changes in growth rate and these are interpreted as occurring with changes in environment (shifts from the Barents to the Norwegian Sea) and changes in physiology e.g. maturation of the gonads. Further research is needed to provide an unequivocal link between the ring structures, maturation and spawning.

5 Guidelines for sampling

5.1 PGCCDBS guidelines

PGCCDBS (ICES, 2009, Annex 10) lists a number of guidelines which according to them should be regularly evaluated based on research development and the experience from maturity staging workshop. WKHERMAT considered each of the guidelines and their relevance for NSSH, and the results from this exercise are listed below.

1) For survey data to be used in maturity index of the spawning stock, the survey must be conducted at the right time compared to the spawning period and have adequate coverage. If survey data are not available at the right time then histologically validated maturity data obtained outside spawning season can be used, although this should be confirmed on a stock-by-stock basis.

   The main survey for NSSH is conducted in May, after the spawning season, which lasts from mid February to mid March. The maturity staging from this survey will therefore be representative for the spawning stock in the sampling year and is based on post spawning information. Gonads classified based on macroscopic inspection on the survey have been validated by histological verification. However, it is recommended that staff from all five parties responsible for maturity staging on the May survey, participate in WKMSHS in 2011 where standardisation of maturity staging of herring will be considered. Samples for this workshop should be collected during the 2010 May survey. A problem with the survey seems to be a difference in catchability between immature and mature part of the same age class and this need to be further addressed.

2) Where valid (see 3) maturity data are available from market samples they can be used to estimate maturity. This is mainly the case for species with a protracted spawning season where survey data do not cover the whole spawning season or stock area. Also, if survey and market data do not show systematic differences they can be used together.

   The commercial catches of NSSH consist almost only of mature herring. Market samples are not relevant for this stock since no fishery is allowed on immature herring. This is regulated with a minimum landing size of 25 cm and a moratorium on fishing in the distribution area of immature fish in the Barents Sea.

3) Maturity data from market samples should be collected during the whole prespawning (for determinate species) or spawning (for indeterminate species) season on a métier based sampling programme, and cover the whole stock distribution area.

   Not relevant

4) As with market samples, on-board samples should be collected on a métier basis to avoid gear and fleet selectivity effects and collected from the correct time and spatial frame compared to spawning.

   Not relevant. The required information on maturity is not related to métier but should be related to the stock. In the case of Norwegian spring spawning herring, métier related information would be biased because it would not include immature herring

5) If possible, maturity staging should be done on board the survey vessel.

This is the current approach.

6) A comprehensive illustrated manual should be available for all stocks requiring maturity observations.

This was discussed and a manual on maturity stages for Baltic herring was circulated. This manual included high quality photos of the different maturity stages and it was considered a very useful tool. Presently only written descriptions of the stages are included in the manual for the May survey. It was recommended that the WGNAPES manual should be updated to include high quality photos of maturity stages on NSSH.

7) Macroscopic maturity scales used should be validated, either histologically or by another appropriate way.

This has been done but will be further explored during WKMSHS in 2011.

8) Plot and map the data collected to assess differences by source, strata, location and time.

This is in agreement with WKHERMAT

9) Length stratified maturity data should be weighted by the length distribution. If samples are collected from a random sampling scheme or the stock is assessed on a length basis, no weighting according to the length distribution is required.

No length stratification is currently done. The samples are taken at random.

10) If the fish maturation process is dependent on age and/or sex as well as length then a Sex-Maturity-Age-Length-Key (SMALK) should be used. Age reading precision is important in this context.

There are no indications in published literature of sexual dimorphism in growth of NSSH and according to Toresen (1990) inter-annual variations in maturity-at-age can be explained by variations in growth. There is therefore no reason to use SMALK.

11) If the stock shows a sexual difference in maturity a female maturity ogive should be used, or the effect of combining both sexes considered in detail.

See 10

12) If the maturity data are modelled, a Binomial GLM with logit link is current standard practice. Alternative approaches should be compared against this baseline approach.

Not relevant

13) Check appropriate model diagnostics.

Not relevant

14) Report the number of maturity staged fish used to calculate the estimates. If length classes are used, report the width of length classes.

WHHERMAT agrees with PGCCDBS on this comment.

15) Report the number of samples or hauls that the maturity staged fish came from. This is likely to be more representative of the effective sample size.

For EU countries there is an obligation in the NP to report the number of measurements in their annual Technical Report. WHHERMAT agrees with PGCCDBS on this comment.

16) When maturity estimates (as proportions) are reported to DCR specifications (Commission Decision 2008/949/EC), calculate the mean confidence

interval width for the age and/or length range which correspond to a 20 % and 90% of mature fish. Convert this to a precision level using:

if half confidence interval width is less than 0.4 then the precision level is 1

if half confidence interval width is less than 0.25 then the precision level is 2

if half confidence interval width is less than 0.05 then the precision level is 3

Optionally, report the range of precision levels achieved as well as the mean level

Presently it is not possible to comply with the DCR specification of precision. The calculation of precision is not only dependent on measurements of maturity of individual fish in the surveys in the Norwegian Sea and in the Barents Sea. The identification of maturation in the fish samples is simple and, if this is carried out by trained staff, there is almost no measurement error. However for the calculation of the proportions mature by age, the measurements from the Norwegian Sea and Barents Sea should be combined and weighted over their local density. This means that additional information is required on the spatial distribution by age group. The presently available information on the distribution of the relevant age groups (3, 4 and 5) by the survey is considered to be biased because of different survey catchability in the Norwegian Sea and the Barents Sea and can therefore not be used.

5.2 Improvements of the Ecosystem survey in the Nordic Seas in May

The time series from this survey is still short and there seems to be a problem with catchability that needs to be addressed. However, collecting maturity data for the Norwegian spring-spawning herring in the coordinated May survey in Norwegian Sea and Barents Sea has the potential to provide data that can be used to estimate maturity ogive of the stock inter-annually, particularly if it is improved in some aspects. These aspectsinclude:

1) Improve the acoustic abundance estimation insuring that young year classes are well represented. This improvement should include the use of side-sonar in combination with echosounder to estimate possible underestimation in the acoustic measurements of the young age classes caused by avoidance to the approaching research vessel.
2) Improvements of the fishing gear used for sampling, particularly in areas where young year classes exists and sampling has been problematic, to limit the amount of fish escaping the gear and possibly causing a skewed representation of the stock composition
3) Increase the number of hauls sampled in the survey to insure that young age classes are well represented.
4) Improve sub-sampling routines.
5) Insure that the subjective maturity staging is correct.

Acoustic abundance estimation

IMR has developed the Large Scale Survey System for processing and analyzing multi-frequency acoustic data. This system handles data from both echosounders and sonars: multi-frequency echo sounder, EK60, *Multibeam sector scanner sonar, MS70*, Multibeam omnidirectional sonar, SH80 (Figure 5.2.1). This is an advantage for abundance estimation, given that pelagic fish often tend to escape research vessels, and the use of sonar in combination with echosounder makes it possible to adjust for this avoidance.

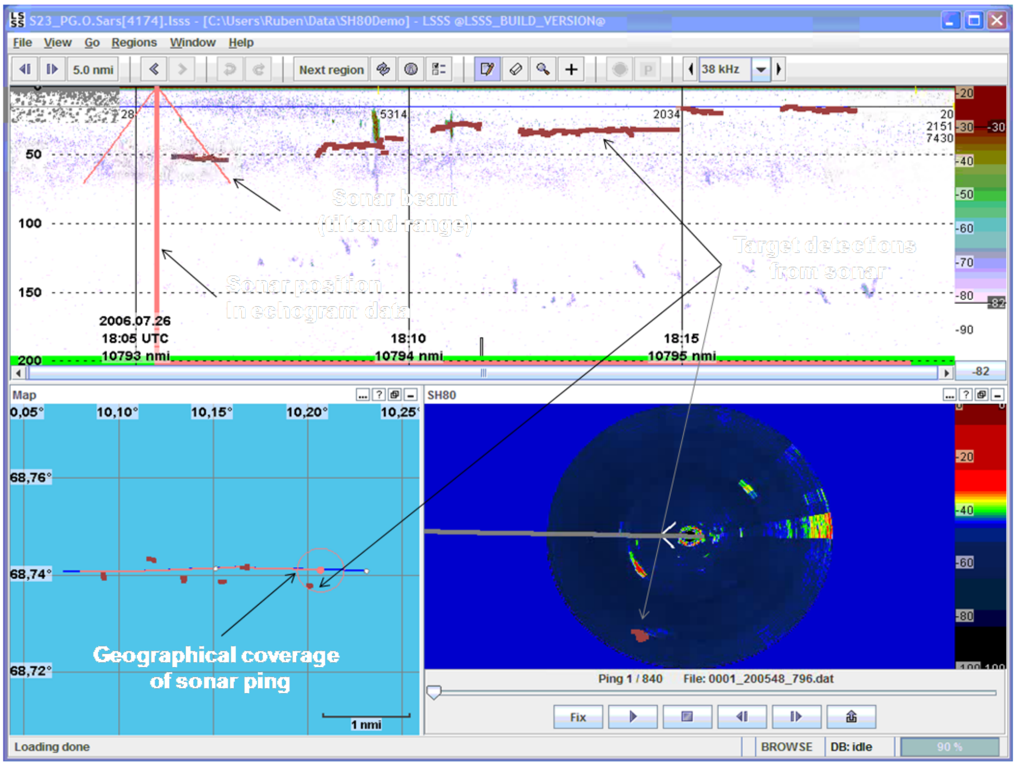

Figure 5.2.1. Large scale survey system (LSSS) demonstrating the use of SH80 sonar data in combination with EK60-data (Pena et al. unpublished).

The experience from surveys in the Norwegian Sea is that young herring tend to avoid the vessel more that the old herring. This is due to the fact that young herring tend to stay closer to the surface than the older herring. As a result it is very likely that we underestimate young age classes in the survey. The use of LSSS and combination of echo sounder and sonar in abundance estimation may solve this problem in the future.

Support for this recommendation is found in a recent survey off Vesterålen northern Norway (Pena *et al.* unpublished). In this survey they observed a high number of herring schools with the sonar, and very few with the echo sounder. The distribution based on sonar data, was very different from that found with echo sounder, as shown in Figure 5.2.2. The picture shown in Figure 5.2.2 is comparable with what is experienced during the May survey in the northeastern Norwegian Sea and the Barents Sea in years with large year classes recruiting to the spawning stock.

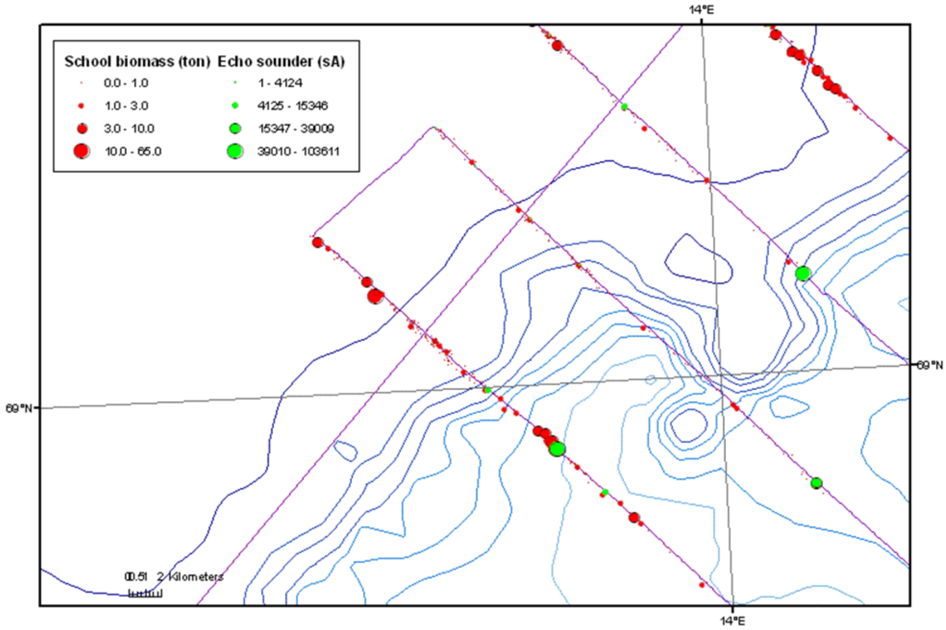

Figure 5.2.2. Comparison between observed distribution and density of young herring schools off Vesterålen, northern Norway, using sonar (red dots) and echo sounder (green dots) (from Pena et al. unpublished).

Trawling

Proper species allocation of the acoustic records is not possible if no trawl information is available. The general rule is to make as many trawl hauls as possible, especially if echo traces are visible on the echosounder after a blank period.

The principal objective is to obtain a sample from the school or the layer that appears as an echo trace on the sounder by means of directed trawling (figure 5.2.3). The type of trawling gear used is not important as long as it is suitable to catch a representative sample of the target-school or layer.

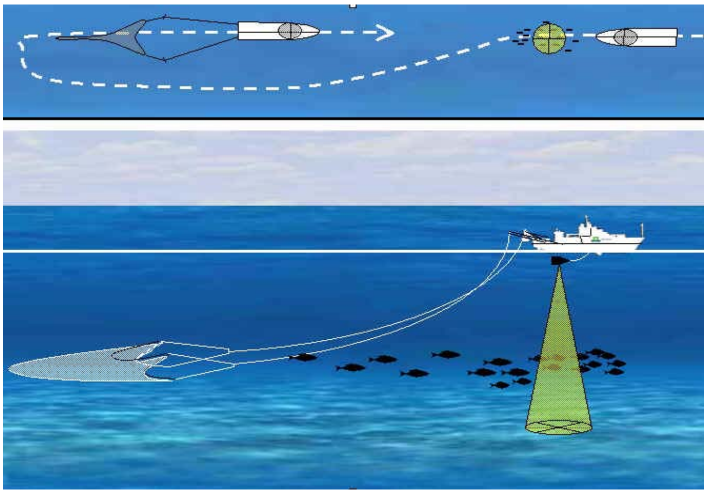

Figure 5.2.3. Schematic overview of how to shoot the gear when back trawling.

During trawling it is important to take note of the traces on the echosounder and the netsonde in order to judge if the target-school entered the net or if some other traces contaminate the sample. It is recommended that notes are made on the appearance and behaviour of fish in the net during every haul. If a target is missed during a haul, the catch composition should not be used for species allocation.

It is recommended that all vessels equipped with sonar use this during the catch operation. The use of sonar during trawling may increase the chance of representative catch, as one actively may turn the vessel in the directions the schools are avoiding using tracking functions in the sonar. This method may also be used for deep and shallow schools. When trawling on layers, this may not be necessary.

If surface schools are known to occur in the area it is often advisable to take occasional surface trawls even in the absence of any significant marks, especially at night time this has proven to be successful.

Number of trawl hauls

In general for estimating population characteristics, it is best to collect a few fish from as many hauls/catches as possible. This is because fish caught together tend to be more similar than fish in the entire population (*i.e.* there is positive intra-cluster correlation). The practical implication of positive intra-cluster correlation is that a sample of fish caught in clusters will generally contain much less information on the population structure than an equal number of fish sampled at random, that is the effective sample size is much smaller than the total number of fish sampled. Therefore, to increase the precision of the acoustic-based estimates, more hauls should be taken, if possible, rather than increase the number of fish sampled from each haul. For gauging survey precision, the effective size should be reported since it is much more informative than the total number of fish sampled.

Sub-sampling

Sub-samples of the trawl catches are considered random and it is important that such sampling is undertaken in a correct way. As an example, data from the Norwegian part of the survey was analysed. For the Norwegian part of the survey up to 100 fish are length measured from each trawl catch. From these, a sub-sample of 30 fish are aged. In order to check how representative these fish are, the length distributions from these two sub-samples were compared for all the years 2005-2009 (only Norwegian data) using a Kolmogorov-Smirnov non-parametric test. The analyses showed that for some of the years a large number of the trawl stations had significantly different length distributions between the two sub-samples. In order to improve this is it recommended to improve routines in order to make sure that the sub-sample of fish is not selected in a systematic way from the sample.

6 Discussion and conclusions

The dynamics of the spawning stock size of Norwegian spring spawning herring have been large over the last century. In that period the stock has collapsed mainly due to overfishing and has recovered to its previous level as a results of an income of a number of strong year classes and rigorous stock management. The stock is assessed by ICES, presently by WGWIDE. The mature part of the stock, the spawning stock biomass, is estimated by applying a proportion mature by age maturity-ogive to the stock estimates by age. In 2008, ICES carried out a benchmark assessment on Norwegian spring spawning herring. In the absence of relevant data, maturity at age was not considered at this benchmark assessment. This was one of the reasons for holding this workshop.

Over the past 10 years ICES has used a constant maturity ogive in the assessment of NSSH, except for the 2002 year class. This year class was assumed to mature earlier, and higher values for the proportion mature for ages 3, 4 and 5 were used in the assessment and forecast. This assumption was based on information from surveys, indicating that this year class was very abundant, predominantly grew up in the Norwegian Sea, showed a higher growth than usual and was close to fully mature at age 4. The assumption made by the WG had large consequences for the contribution of the 4-year-olds to SSB in 2006 which was, at that time, more than 1 million tonnes higher compared to using the fixed maturity values. The estimate of the size of this year class has progressively increased in the assessment in the following five years by about 100% and the assumptions concerning the maturity ogive of this year class makes a difference of 3 million tonnes in the estimate of SSB in 2006. Therefore it was considered important to evaluate the maturity data available especially for recent years.

WKHERMAT considered information on maturity from three sources: 1) the maturity matrix used by the ICES assessment working group, 2) survey data on maturity by area back to 2002 collected by all participating countries during the May survey and 3) a matrix of maturity data estimated from back calculation of herring scales. As far as known all sources represent maturity for males and females combined.

In summary, all those sources indicate that most 1 and 2-year-old herring are immature and most herring of 6 years and older are mature. However, there are differences between the sources in 3, 4 and 5 year old herring. These are the age groups when the herring usually becomes first mature and therefore matter most in the assessment and were the focus of the WK.

The maturity matrix used by ICES goes back to 1907. Only the data after 1950 were considered by the WK. The matrix shows several periods of constant maturity at age. There are also periods with large or small annual changes. Documentation on the source of information and the justification of changes is almost absent (literature and a number of old WG reports were checked by WKHERMAT). The WK assumed that the major source of information used by ICES would probably come from surveys on the wintering and spawning grounds in the Norwegian Sea. It is also likely that no information from the Barents Sea was available, since surveys in this area have only been carried out in recent years. It is likely that for some periods no actual maturity material has been considered - such as recent years - or that the available information had not lead to a decision to change the maturity-ogive in some period. 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 are not explained.

Maturity data measured during the international herring surveys on the feeding grounds in May are available from 2002 onwards. The surveys cover the distribution of the whole stock; the predominantly adult part in the Norwegian Sea and the predominantly immature part in the Barents Sea. In principle this is the ideal situation to obtain unbiased estimates of a maturity ogive. Although, the survey is carried out after spawning time, the workshop did not consider this to be a problem. In practice there are no problems during the survey in defining whether the fish had spawned this year or not (post spawning estimates). However, the survey is too early to indicate whether the fish will spawn in the next year.

The aggregated data from the surveys were available for three areas; two in the Norwegian Sea and one in the Barents Sea. For the Barents Sea only four years of data were available. 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. The low sampling in some areas contributes to the annual variation. Three, four and five year old fish occur in both areas. The deviation of a maturity ogive from the survey data compared to back-calculated values appeared to be problematic. The maturity ogive must be representative for the whole stock and must be based on information from the Norwegian Sea and Barents Sea combined taking into account the distribution of these age groups. It was suggested the acoustic measurements in the areas were used for weighting. However, there appear to be differences in the catchability in the Norwegian Sea and Barents Sea. Due to differences in behaviour of herring in the two areas, the avoidance of the herring to the research vessel in the Barents Sea seems to be higher than in the Norwegian Sea. This means that Barents Sea abundances are not estimated adequately and the acoustic information would provide a biased estimate of the maturity ogive.

In order to be able to combine the maturity measurements in both areas, sufficient quantitative data on the distribution of 3, 4 and 4 year old herring are needed. This may be obtained from the survey if reliable estimates of catchability in both areas can be obtained. This may require additional research by research vessels.

The Data Collection Framework, which applies to EU Member States, require Member States to target certain precision levels in their sampling programme for maturity data and to calculate estimates of precision for their achieved sampling. It is important to realise that there seem to be no major problems in defining the maturity stage of a fish as long as experienced staff are involved. This can be done with high precision. However, the precision of the maturity ogive on the relevant age groups mostly depends on the additional information on the distribution of a few age groups, which need to come from other sources. Therefore, it is not possible to estimate precision on maturity data alone. This can only be done if additional information is available. It is likely that a number of other stocks face comparable problems.

The third source of information came from interpretation of the ring pattern on the scales of more than 150 000 aged herring. This data source has been used in a number of publications by Engelhard and Heino in recent years. The age of each fish can be estimated from the number of rings on the scale. Based on a change in the ring pattern also the age of first maturation can be estimated. There are still some uncertainties regarding the interpretation of the results of the back calculation of the first maturation. There might be a bias in the data source, since the information is mostly coming from older fish (survivors) with possible different life history characteristics as young fish. This could not be tested during the meeting because the individual data were not accessible. However, after the meeting it will be tested whether there is a difference in first age of maturity estimated from scales from relative old fish and young fish. Also, the change in the ring pattern could be interpreted as the migration from the Barents Sea to the Norwegian Sea ecosystem. However, this migration and the first maturation often occur at the same time. A big advantage of this data set is that it allows the construction of maturity ogives back to back to 1929 derived by a consistent approach and is reproducible. It does not have the weighting problems as identified by the survey data.

The back calculation data set indicates 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 the assessment by ICES. The estimate of the maturity of this year class at age 4 used in the assessment by ICES was 90% while the back calculation data suggest it was near 30% and not very different from the surrounding year classes. The ICES working group estimate was based on surveys, which indicated that, in contrast to other years, this year class was mainly distributed in the Norwegian Sea and was fully covered by the surveys in that area. These surveys also indicated that the 2002 year class was close to fully mature at age 4 and provided the first estimate of its year class strength. The value of 30% maturation at age 4, obtained from the back calculation, implies that a large immature part of this year class has not been seen by the survey. It may have been distributed in coastal areas not covered by the survey or its abundance in the Barents Sea may be underestimated by the survey through limited coverage of the area or a low catchability caused by avoidance to the vessel. The increased estimates of the size this year class in successive years by the ICES assessments support this.

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.

A comparison of the SSB derived from the ICES WG matrix of maturity data and the back calculation data is shown in Figure 6.1. Although there are sometimes large differences in the maturity-at-age data between the data sets, the trends in SSB from both data sets are very similar. There appear only differences in a few short periods where the strong year classes enter the spawning stock. These contribute a large amount to the SSB and the different values used at age 3, 4 and 5 in both sets cause the difference.

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.

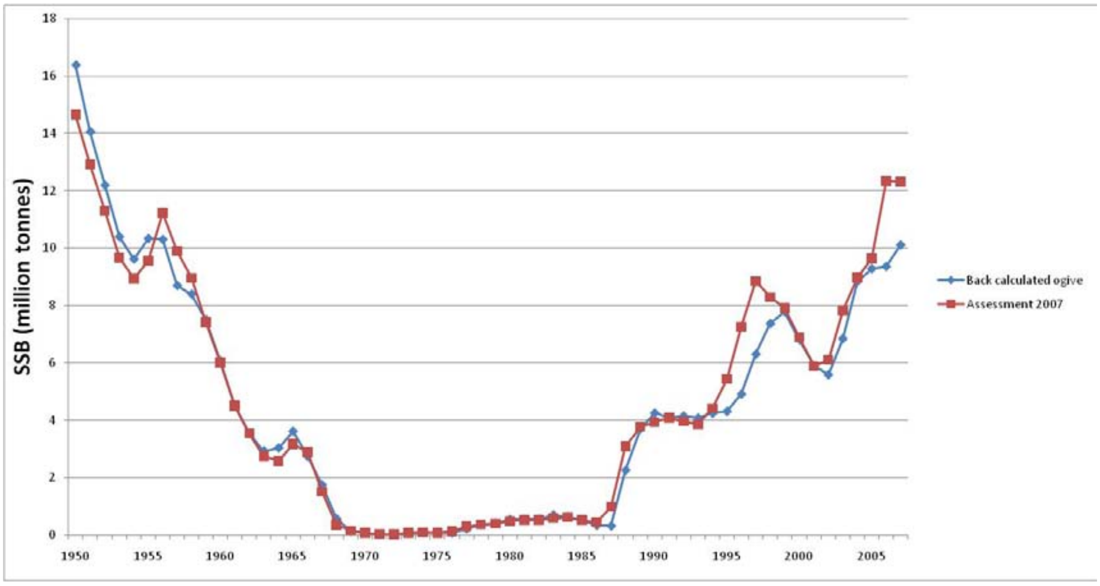

Figure 6.1. SSB estimated using assessment ogive and back-calculated ogive.

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Annex 1: List of participants

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Annex 2: Agenda

Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT), Institute of Marine Research, Bergen 1-3 March 2010

Agenda

Venue: Store dypet, IMR, Nordnesgaten 33

Day 1

10:00-10:15	Welcome, presentation of participants, ToRs, adoption of agenda (Erling Kåre Stenevik, EKS)
10:15-10:45	Introduction and background for the meeting (Frans van Beek, FvB)
10:45-11:00	Coffee break
11:00-11:15	Report from PGCCDBS, WKMAT and WKMOG (EKS)
11:15-11:30	History of maturity ogive in NSSH assessment (EKS)
	Other stocks such as North Sea herring?
11:30-11:45	Back-calculation of maturity ogive (EKS)
11:45-12:30	Discussion
	How important is the maturity ogive in assessment?
	Is the use of a fixed maturity ogive in the assessment of NSSH justified?
	Is the method of back-calculation an alternative for use in assess ment?
12:30-13:30	Lunch
13:30-15:00	Discussion cont.
15:00-15:15	Coffee break
15:15-18:00	Discussion cont.
19:00	Dinner at a local restaurant BOHA, compliments from IMR

Day 2

09:00-09:30	Maturity cycle in NSSH. What is the best time to sample? (Aril Slotte, AS)
09:30-10:00	Estimates of maturity ogive from the May survey (EKS)
	Distribution/migration
10:00-10:15	Coffee break
10:15-12:30	Discussion
	Can the May survey be used to produce maturity ogive?
	Do we need other data from surveys/commercial catches?
12:30-13:30	Lunch

13:30-15:00	Discussion – guidelines for sampling data on maturity ogive
15:00-15:15	Coffee break
15:15-17:00	Discussion – guidelines for sampling data on maturity ogive
17:00-18:00	Conclusions and start structuring the report

Day 3

09:00-10:00	Writing the report
10:00-10:15	Coffee break
10:15-12:30	Writing the report
12:30-13:30	Lunch
13:30-15:00	Writing the report
15:00	Adjourn

Annex 3: Recommendations

Recommendation	For follow up by:
1.Increase the number of hauls sampled in the May survey to insure that young age classes are well represented	WGNAPES
2. Improve methods of acoustic registration and trawling during the May survey in order to sample representatively for all age-classes so that appropriate weightings of maturity data from each area can be obtained	WGNAPES
3.Reconsider the maturity values used for the 2002 year class in the assessment	WGWIDE
4.Consider the potential use of the back-calculated maturity ogive as an alternative to the historical ogive presently used by the WG	WGWIDE
5.Participation in WKMSHS	

Recommendation 1

WKHERMAT recommends to increase the number of hauls sampled in the May survey to insure that young age classes are well represented

rationale:

In general for estimating population characteristics, it is best to collect a few fish from as many hauls/catches as possible. This is because fish caught together tend to be more similar than fish in the entire population (*i.e.* there is positive intra-cluster correlation). The practical implication of positive intra-cluster correlation is that a sample of fish caught in clusters will generally contain much less information on the population structure than an equal number of fish sampled at random, that is the effective sample size is much smaller than the total number of fish sampled. Therefore, to increase the precision of the acoustic-based estimates, more hauls should be taken, if possible, rather than increase the number of fish sampled from each haul. For gauging survey precision, the effective size should be reported since it is much more informative than the total number of fish sampled.

Recommendation 2

WKHERMAT recommends improving methods of acoustic registration and trawling during the May survey in order to sample representatively for all age-classes so that appropriate weightings of maturity data from each area can be obtained.

rationale:

The large differences in maturity at age 4 between the back-calculations and direct estimates from the May survey may be caused by differences in catchability (both acoustic and in trawl samples) between young and old ages and between immature and mature components at the same age. Therefore, it is needed to investigate how sampling procedures could be improved in order improve on this. In addition to increasing the number of trawl stations it is suggested to increase the use of sonar to get a better estimate of the fish which are distributed close to the surface and may avoid the vessel and not be registered by the echo sounder.

Recommendation 3

WKHERMAT recommends WGWIDE to reconsider the maturity values used for the 2002 year class in the assessment

rationale:

The maturity ogive for large 2002 year-class was treated differently than other year-classes in the assessment largely based on data from the May surveys. WKHERMAT compared estimates of maturity ogives based on the May survey for the 2002 year class with neighboring year-classes. It was shown that estimates of maturity at age 4 from the May survey are high also for the neighboring year-classes and it is likely that the May survey overestimate maturity at age 4. Back-calculation of maturity at age 4 for the 2002 year-class is much lower (0.3) than the values based on surveys. WKHERMAT therefore concluded that the adjustments of maturity at age for the 2002 year-class is not justified and recommends that they are reconsidered by WGWIDE.

<u>Recommendation 4</u>

WKHERMAT recommends WGWIDE to consider the potential use of the back-calculated maturity ogive as an alternative to the historical ogive presently used by WGWIDE.

rationale:

The back calculation data set indicates 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 the assessment 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.

<u>Recommendation 5</u>

WKHERMAT recommends that technicians involved in maturity staging during the May survey participate in WKMSHS in order to calibrate the staging procedures.

It was discovered that in some years the maturity staging done during the survey could be questioned. Particularly, in 2005 one of the vessels had a lot of immature fish up to age 15 in the southwestern part of the Nowegian Sea. This is highly unlikely and could be caused by inexperienced staff responsible for the staging. It is suggested here to sample gonads during the May survey and possibly also other surveys in order to do an intercalibration during the Workshop on Sexual Maturity Staging of Herring and Sprat (WKMSHS) in spring 2011. Staff from all nations participating in the May survey should attend the workshop.

Annex 4 Maturity ogives

Maturity ogive used by ICES in assessment

	AGE															
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0	0	0	0	0.1	0.3	0.6	0.9	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
1952	0	0	0	0	0.1	0.3	0.6	0.9	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
1954	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1
1955	0	0	0	0.1	0.2	0.4	0.9	1	1	1	1	1	1	1	1	1
1956	0	0	0	0.1	0.2	0.4	0.9	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
1958	0	0	0	0.1	0.2	0.4	0.9	1	1	1	1	1	1	1	1	1
1959	0	0	0	0.1	0.2	0.4	0.9	1	1	1	1	1	1	1	1	1
1960	0	0	0	0.1	0.2	0.4	0.9	1	1	1	1	1	1	1	1	1
1961	0	0	0	0	0.4	0.7	0.9	1	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1
1964	0	0	0	0	0.1	0.3	0.3	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.3	0.4	0.8	1	1	1	1	1	1	1	1	1
1966	0	0	0	0	0.2	1	1	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0	0.2	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0	0.8	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.6	0.9	1	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0.1	0.1	0.3	0.2	1	1	1	1	1	1	1	1	1
1971	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.1	0.3	0.6	0.9	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
1974	0	0	0	0.5	0.9	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
1976	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.7	0.9	1	1	1	1	1	1	1	1	1	1	1
1978	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1979	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1	1
1980	0	0	0	0.3	0.5	1	1	1	1	1	1	1	1	1	1	1

Maturity ogive used by ICES in assessment cont.

	AGE															
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1981	0	0	0	0.3	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1982	0	0	0	0.1	0.5	0.7	1	1	1	1	1	1	1	1	1	1
1983	0	0	0	0.1	0.5	0.7	0.7	1	1	1	1	1	1	1	1	1
1984	0	0	0	0.1	0.5	0.9	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
1986	0	0	0	0.1	0.2	0.9	1	1	1	1	1	1	1	1	1	1
1987	0	0	0	0.1	0.3	0.9	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
1989	0	0	0	0.1	0.3	0.9	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
1991	0	0	0	0.1	0.7	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
1993	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1
1994	0	0	0	0	0.3	0.8	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
1996	0	0	0	0	0.3	0.9	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
1998	0	0	0	0	0.3	0.9	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
2000	0	0	0	0	0.3	0.9	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
2002	0	0	0	0	0.3	0.9	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
2004	0	0	0	0	0.3	0.9	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
2006	0	0	0	0	0.9	0.9	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
2008	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1

Back-calculated maturity ogive

	AGE															
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0.0	0.0	0.0	0.0	0.2	0.8	1.0	1.0	1	1	1	1	1	1	1	1
1951	0.0	0.0	0.0	0.0	0.2	0.8	1.0	1.0	1	1	1	1	1	1	1	1
1952	0.0	0.0	0.0	0.0	0.1	0.6	1.0	1.0	1	1	1	1	1	1	1	1
1953	0.0	0.0	0.0	0.0	0.3	0.4	0.9	1.0	1	1	1	1	1	1	1	1
1954	0.0	0.0	0.0	0.0	0.1	0.7	0.9	1.0	1	1	1	1	1	1	1	1
1955	0.0	0.0	0.0	0.1	0.4	0.4	1.0	1.0	1	1	1	1	1	1	1	1
1956	0.0	0.0	0.0	0.0	0.5	0.7	0.6	1.0	1	1	1	1	1	1	1	1
1957	0.0	0.0	0.0	0.0	0.3	0.8	0.8	0.7	1	1	1	1	1	1	1	1
1958	0.0	0.0	0.0	0.0	0.3	0.5	0.9	0.9	1	1	1	1	1	1	1	1
1959	0.0	0.0	0.0	0.0	0.7	0.8	1.0	0.9	1	1	1	1	1	1	1	1
1960	0.0	0.0	0.0	0.0	0.3	0.9	0.9	1.0	1	1	1	1	1	1	1	1
1961	0.0	0.0	0.0	0.0	0.1	0.8	1.0	0.9	1	1	1	1	1	1	1	1
1962	0.0	0.0	0.0	0.0	0.1	0.7	1.0	1.0	1	1	1	1	1	1	1	1
1963	0.0	0.0	0.0	0.0	0.1	0.4	1.0	1.0	1	1	1	1	1	1	1	1
1964	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.0	1	1	1	1	1	1	1	1
1965	0.0	0.0	0.0	0.0	0.5	0.4	0.9	0.8	1	1	1	1	1	1	1	1
1966	0.0	0.0	0.0	0.0	0.5	0.7	0.9	1.0	1	1	1	1	1	1	1	1
1967	0.0	0.0	0.0	0.0	0.3	0.8	1.0	1.0	1	1	1	1	1	1	1	1
1968	0.0	0.0	0.0	0.0	0.0	0.7	0.9	1.0	1	1	1	1	1	1	1	1
1969	0.0	0.0	0.0	0.1	0.2	0.3	1.0	1.0	1	1	1	1	1	1	1	1
1970	0.0	0.0	0.0	0.0	0.4	0.3	0.4	1.0	1	1	1	1	1	1	1	1
1971	0.0	0.0	0.0	0.0	0.1	0.7	1.0	1.0	1	1	1	1	1	1	1	1
1972	0.0	0.0	0.0	0.0	0.4	0.3	1.0	1.0	1	1	1	1	1	1	1	1
1973	0.0	0.0	0.0	0.1	0.6	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1974	0.0	0.0	0.0	0.0	0.6	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1975	0.0	0.0	0.0	0.1	0.5	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1976	0.0	0.0	0.0	0.1	0.9	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1977	0.0	0.0	0.0	0.3	0.8	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1978	0.0	0.0	0.0	0.2	0.9	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1979	0.0	0.0	0.0	0.1	0.9	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1980	0.0	0.0	0.0	0.1	0.9	1.0	1.0	1.0	1	1	1	1	1	1	1	1

Back-calculated maturity ogive cont.

	AGE															
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1981	0.0	0.0	0.0	0.1	1.0	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1982	0.0	0.0	0.0	0.1	0.8	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1983	0.0	0.0	0.0	0.1	0.9	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1984	0.0	0.0	0.0	0.1	0.7	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1985	0.0	0.0	0.0	0.1	0.8	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1986	0.0	0.0	0.0	0.0	0.5	0.9	0.9	1.0	1	1	1	1	1	1	1	1
1987	0.0	0.0	0.0	0.0	0.1	0.8	0.9	0.9	1	1	1	1	1	1	1	1
1988	0.0	0.0	0.0	0.0	0.2	0.7	0.9	1.0	1	1	1	1	1	1	1	1
1989	0.0	0.0	0.0	0.0	0.4	0.8	1.0	1.0	1	1	1	1	1	1	1	1
1990	0.0	0.0	0.0	0.2	0.5	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1991	0.0	0.0	0.0	0.0	0.9	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1992	0.0	0.0	0.0	0.0	0.8	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1993	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0	1	1	1	1	1	1	1	1
1994	0.0	0.0	0.0	0.0	0.1	0.9	1.0	1.0	1	1	1	1	1	1	1	1
1995	0.0	0.0	0.0	0.0	0.0	0.6	1.0	1.0	1	1	1	1	1	1	1	1
1996	0.0	0.0	0.0	0.0	0.0	0.5	0.9	1.0	1	1	1	1	1	1	1	1
1997	0.0	0.0	0.0	0.1	0.0	0.4	0.9	1.0	1	1	1	1	1	1	1	1
1998	0.0	0.0	0.0	0.0	0.6	0.4	0.9	1.0	1	1	1	1	1	1	1	1
1999	0.0	0.0	0.0	0.0	0.3	0.9	0.9	1.0	1	1	1	1	1	1	1	1
2000	0.0	0.0	0.0	0.0	0.2	0.8	1.0	1.0	1	1	1	1	1	1	1	1
2001	0.0	0.0	0.0	0.0	0.3	0.9	0.9	1.0	1	1	1	1	1	1	1	1
2002	0.0	0.0	0.0	0.0	0.1	0.9	1.0	1.0	1	1	1	1	1	1	1	1
2003	0.0	0.0	0.0	0.0	0.2	0.7	1.0	1.0	1	1	1	1	1	1	1	1
2004	0.0	0.0	0.0	0.0	0.3	0.9	1.0	1.0	1	1	1	1	1	1	1	1
2005	0.0	0.0	0.0	0.0	0.3	0.9	1.0	1.0	1	1	1	1	1	1	1	1
2006	0.0	0.0	0.0	0.0	0.3	0.8	1.0	1.0	1	1	1	1	1	1	1	1
2007	0.0	0.0	0.0	0.0	0.1	0.7	0.9	1.0	1	1	1	1	1	1	1	1

Maturity ogives from the May survey for the entire distribution area, weighted with acoustic estimates by the three sub-areas. Note that area I (Barents Sea) was not covered in 2008.

	AGE													
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2005	0	0	0.0	0.5	0.9	1	0.9	0.9	0.8	0.7	0.9	0.8	0.9	0.9	0.9
2006	0	0	0.1	1.0	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2007	0	0	0.0	0.8	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2008	0	0	0.4	0.8	1.0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2009	0	0	0.4	0.7	0.9	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Maturity data from the May survey by area in 2005

Area III	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1			1			1									
maturity 2		1	45	8	6	46	71	10	9	6	6	17	10	5	1
maturity 3				1	3	21	32	4	1		3		1		
maturity 4															
maturity 5								1	1			1			
maturity 6						1									
maturity 7				1	8	12	8	1	1		1	3	2		
maturity 8			5	7	40	209	267	49	39	11	29	62	133	46	18
Immature	0	1	46	8	6	47	71	10	9	6	6	17	10	5	1
Mature	0	0	5	9	51	243	307	55	42	11	33	66	136	46	18
Acoustic estimate	0	0	0	5.7	75.5	439	669.1	115	87.9	28.7	69.7	146.4	271	86.4	22
Maturity at age			**0.1**	**0.53**	**0.89**	**0.84**	**0.812**	**0.85**	**0.82**	**0.647**	**0.846**	**0.795**	**0.932**	**0.902**	**0.9474**

Area II	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		4	54			1									
maturity 2		39	770	50	15	7	1								
maturity 3			17	10	11	20	19	3		1		1		2	
maturity 4			1		5	1	2						1	1	
maturity 5															
maturity 6			1			1									
maturity 7			3	2	1	24	21	1	2	2	3		2	1	1
maturity 8			19	25	102	433	292	28	14	5	5	9	30	13	
Immature	0	43	824	50	15	8	1	0	0	0	0	0	0	0	0
Mature	0	0	41	37	119	479	334	32	16	8	8	10	33	17	1
Acoustic estimate	0	85.1	2362	221	301	1034	718.8	71.4	31.4	16.5	13.6	23.6	78.4	37.4	0
Maturity at age			**0.05**	**0.43**	**0.89**	**0.98**	**0.997**	**1**	**1**	**1**	**1**		**1**	**1**	**1**

Area I	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1	190	2	22			1									
maturity 2	28	141	112	17	12	6	1								
maturity 3				2	1		1								
maturity 4					1										
maturity 5															
maturity 6						1									
maturity 7			2	34	26	36	13								
maturity 8			10	13	41	162	90	6	4	3	2	2	8	1	
Immature	218	143	134	17	12	7	1	0	0	0	0	0	0	0	0
Mature	0	0	12	49	69	199	104	6	4	3	2	2	8	1	0
Acoustic estimate	183	135	198	78.9	76.6	129	59.7	1.9	0	0	0	0	7.7	0	0
Maturity at age	**0**	**0**	**0.08**	**0.74**	**0.85**	**0.97**	**0.99**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	

Maturity data from the May survey by area in 2006

Area III	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1															
maturity 2															
maturity 3															
maturity 4						1	2				1				
maturity 5						1	1						1		
maturity 6															
maturity 7				1											
maturity 8			1	59	20	66	266	347	41	49	16	27	75	45	21
Immature	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	1	60	20	68	269	347	41	49	17	27	76	45	21
Acoustic estimate	0	0	3.3	400.8	181.1	285.3	1104.6	1299.7	157.5	191.7	49.8	115.2	265.3	168.8	425
Maturity at age			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Area II	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1															
maturity 2			5	6											
maturity 3				10			1							1	1
maturity 4															
maturity 5															
maturity 6				1											
maturity 7			1	91	5	15	44	53	1	1			2	5	2
maturity 8			11	421	12	14	61	71	2	2	2			6	2
Immature	0	0	5	6	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	12	523	17	29	106	124	3	3	2	0	2	12	5
Acoustic estimate		1.3	40.2	2278.9	49.5	162.1	559	695.4	9.5	15.8	6.6	0	7.1	87.4	46.5
Maturity at age			**0.71**	**0.99**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**

Area I	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1	53	190													
maturity 2	2	31	63	10											
maturity 3			5	2											
maturity 4															
maturity 5															
maturity 6															
maturity 7															
maturity 8				1											
Immature	55	221	63	10	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0
Acoustic estimate	37	1486.2	454.1	113	0.1	0.3	1.3	0.9	0	0	0	0	0	0	0
Maturity at age	**0**	**0**	**0.07**	**0.23**											

Maturity data from the May survey by area in 2007

Area III	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		1	2	1											
maturity 2			46	40	8										
maturity 3			1	8	181	18	36	105	103	5	8	1	4	3	4
maturity 4						2	2	3				1			
maturity 5					1					1					
maturity 6															
maturity 7								1							
maturity 8				81	637	54	118	447	362	31	24	15	21	54	51
Immature	0	1	48	41	8	0	0	0	0	0	0	0	0	0	0
Mature	0	0	1	89	819	74	156	556	465	37	32	17	25	57	55
Acoustic estimate			6.4	34.4	1063.4	139.9	333.5	1342.3	1318.4	163.6	130.4	107.3	113.7	350.5	324.3
Maturity at age			**0.02**	**0.68**	**0.99**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Area II	**age 1**	**age 2**	**age 3**	**age 4**	**age 5**	**age 6**	**age 7**	**age 8**	**age 9**	**age 10**	**age 11**	**age 12**	**age 13**	**age 14**	**age 15+**
maturity 1		1	2	1											
maturity 2		1	113	64	10										
maturity 3			2	8	24	3	3	3	4						
maturity 4					2		1								
maturity 5															
maturity 6				1											
maturity 7				1	1			2		1					
maturity 8			30	211	1060	47	50	130	67	7	4	2	3	1	4
Immature	0	2	115	65	10	0	0	0	0	0	0	0	0	0	0
Mature	0	0	32	221	1087	50	54	135	71	8	4	2	3	1	4
Acoustic estimate		22.8	297.2	881.4	3052.3	151.4	178	503.5	277.9	39.7	25.6	16.3	19.4	4.9	17.8
Maturity at age			**0.22**	**0.77**	**0.99**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**

Area I	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		1													
maturity 2	7	74	239	28											
maturity 3			2	9											
maturity 4															
maturity 5															
maturity 6															
maturity 7															
maturity 8															
Immature	7	75	239	28	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	2	9	0	0	0	0	0	0	0	0	0	0	0
Acoustic estimate	25.5	116.8	1045.6	287.1											
Maturity at age	**0**	**0**	**0.01**	**0.24**											

Maturity data from the May survey by area in 2008. Area I (Barents Sea) was not covered in 2008.

Area III	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1						1									
maturity 2															
maturity 3								1							
maturity 4							1		1						
maturity 5															
maturity 6					1										
maturity 7				2	11	81	14	31	53	13	5	1	4	4	3
maturity 8				15	97	440	38	71	219	151	20	6	6	8	23
Immature	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Mature	0	0	0	17	109	521	53	103	273	164	25	7	10	12	26
Acoustic estimate		0.6	0.1	43	232.9	1498	157.7	313.1	864.7	512	89.5	31.7	44.6	62.2	125.4
Maturity at age				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Area II	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		11	2	3											
maturity 2		34	12	69	1	1									
maturity 3			3	110	62	43	5	2	3	2					
maturity 4			1	1	2				1						
maturity 5								1							
maturity 6				1	2	2									
maturity 7				18	28	70	8	13	11	7	1		1		
maturity 8			6	171	172	172	17	12	15	7	5	1		1	2
Immature	0	45	14	72	1	1	0	0	0	0	0	0	0	0	0
Mature	0	0	10	301	266	287	30	28	30	16	6	1	1	1	2
Acoustic estimate		92.5	72.3	1315.7	1452.6	2172.3	188.2	204.6	222.6	187.9	34.5	45.9	4.9	12	14.6
Maturity at age			**0.42**	**0.81**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**

Maturity data from the May survey by area in 2009.

Area III	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1															
maturity 2															
maturity 3					3	23	27	15	9	1	1				
maturity 4							2	1	2	1					
maturity 5								1	1	1					
maturity 6															
maturity 7							1			1					
maturity 8				3	31	112	446	47	96	249	155	20	21	9	34
Immature	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	0	3	34	135	476	64	108	253	156	20	21	9	34
Acoustic estimate	0	0	0	42	712	1937	4985	504	832	1916	1155	134	128	60	182
Maturity at age				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Area II	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		2	11	8	4										
maturity 2			11	7	26	3	1								
maturity 3			2	3	20	31	29	4	1			1	1		
maturity 4				1	1	1		1		2					1
maturity 5						2									
maturity 6					1		1								
maturity 7			1		8	17	15	1	1						
maturity 8			18	35	278	171	149	26	11	19	6	4	1		4
Immature	0	2	22	15	30	3	1	0	0	0	0	0	0	0	0
Mature	0	0	21	39	308	222	194	32	13	21	6	5	2	0	5
Acoustic estimate	5	410	2311	2297	13145	7400	6485	943	409	648	194	128	55	0	73
Maturity at age	**0**	**0**	**0.49**	**0.72**	**0.91**	**0.99**	**0.99**	**1**	**1**	**1**	**1**	**1**	**1**		**1**

Area I	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
maturity 1		22	26	6	2										
maturity 2	2	4	3	2											
maturity 3				1	2										
maturity 4															
maturity 5															
maturity 6															
maturity 7					2										
maturity 8			11	29	45	1									
Immature	2	26	29	8	2	0	0	0	0	0	0	0	0	0	0
Mature	0	0	11	30	49	1	0	0	0	0	0	0	0	0	0
Acoustic estimate	198	496	670	416	435	150	159	27	9	23	9	5	2	0	1
Maturity at age	**0**	**0**	**0.28**	**0.79**	**0.96**	**1**									